Range Management and its Ecological Basis in the Ponderosa Pine Type of Arizona: The Status of Our Knowledge

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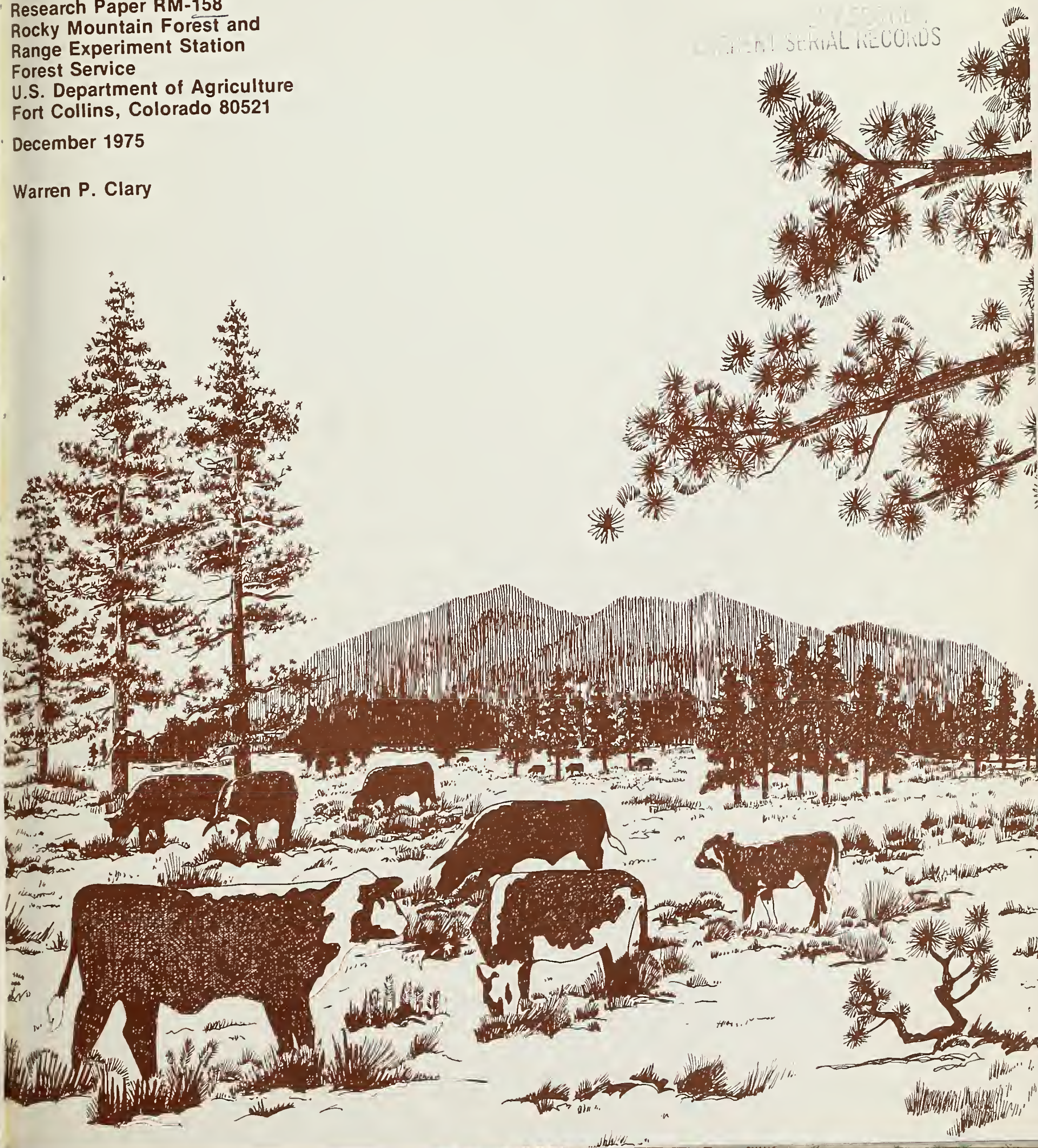

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This paper, intended to serve as a reference for managers of forested ranges, summarizes and evaluates available information about Arizona ponderosa pine-bunchgrass ranges. It covers physical-biological characteristics, factors influencing livestock production, grazing allotment conditions, and economics, and correlates grazing with other uses. Several knowledge gaps are also identified.

Keywords: Range management, grazing systems, pine-bunchgrass range.

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RANGE MANAGEMENT AND ITS ECOLOGICAL BASIS IN THE PONDEROSA PINE TYPE OF ARIZONA:
The Status of Our Knowledge

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Research Highlights

The purposes of this Paper are to summarize and evaluate the available physical, biological, management, and economic data for the Arizona pine-bunchgrass ranges. It provides information intended to help public and private managers of forest-range lands in making resource management decisions, and to help researchers make decisions concerning possible new research directions.

The information provided follows this sequence: physical-biological characteristics of the Arizona ponderosa pine type, factors influencing livestock (primarily beef) production, allotment conditions, economics, and correlation of grazing with other uses and demands. The following conclusions can be drawn from this information:

1. Considerable descriptive information is available for the Arizona ponderosa pine type. Knowledge of geographic, climatic, edaphic, and vegetation characteristics is adequate for use in reaching many management decisions.
2. The successional stages of the bunchgrass ranges appear to be sufficiently understood so that general range condition can be easily recognized.
3. A good background of range seeding information is available, and the causes of livestock losses from poisonous plants are understood.
4. A good information base on forage nutrition applicable to summer grazing has been developed for ranges dominated by Arizona fescue and mountain muhly. This base can be used as a guide to management needs when compared with the nutritional requirements of the livestock in question. Similar nutritional information should be developed for other ecological situations and for other seasons of the year.
5. Information available on the factors influencing herbage yields on volcanic soils should provide usable predictors of herbage production and how it is affected by timber overstory densities and manipulations. Similar information should be developed for sedimentary soils.
6. Potential beef gains can be predicted from nutrient consumption, and potential livestock carrying capacity can be predicted from timber density and forage composition. However, computer models capable of simulating animal distribution are needed to predict changes in **actual** livestock carrying capacity and production so that land managers will have better advance information concerning the effects of vegetation manipulation and various grazing management procedures.
7. The tree basal area that will provide maximum combined product value for joint beef and sawlog production has been determined for ponderosa pine-bunchgrass ranges to be between 45 and 60 square feet per acre.
8. No information was found that suggests that **proper** range use conflicts significantly with other forest uses, although more information is needed concerning the relationships of livestock grazing to nonruminant wildlife and general recreational values.
9. New inventory techniques are needed to provide up-to-date data on forage production and use, range condition and trend, animal numbers, and vegetation types.
10. National Forest System procedures for land use planning in some regions are now based upon assessments of land capability and sensitivity (USDA-FS 1972b). To adequately apply these procedures, information is needed on the impact of livestock use on erosion processes for the various forest and range sites.
11. Information is required concerning the effectiveness of different grazing systems as they **specifically** apply to the Arizona ponderosa pine type. It is suggested that allotment data for the Southwestern Region, R-3 of the USDA Forest Service, be intensively analyzed to document the effect of different grazing systems applied under different conditions.
12. A major effort in habitat typing has been proposed for the Southwest. This information is considered to be an essential base for future management planning, including grazing management. Three of the major differences that can be expected among habitat types are in forage production potential, initial composition of forage plants, and the manner in which the composition responds to different grazing management procedures.

13. Much of the work to be done on Arizona ponderosa pine ranges is in the area of range condition improvement. Past managerial shortsightedness often resulted in depleted ranges and impaired environmental quality. Sufficient information is available—and has been for years—to define a suitable path toward maintenance and improvement of the western ranges (USDA-FS 1936, Stoddart and Smith 1943, Sampson 1952). Where applied, existing information in the areas of forage use, livestock distribution, rest or deferment, reseeding, and control of invading plants will go a long way toward gradually getting ranges back in top shape. The difficulty, of course, is that most of these measures require added investment or intensified management, which necessitates examination of short- and long-run economic and financial tradeoffs. As these decisions can directly affect ranching profits, more information is needed on the economics and finance of range improvements. This kind of information will give managers a stronger basis for making tradeoff assessments and substantiating their decisions.
14. The day of functionalism (management for individual products or values) in managing most forest-range lands is close to being over. Range managers, particularly those dealing with public lands, need to maintain a multiple-use management perspective. All potential uses of the forested range have to be jointly considered when changes in management of a range are contemplated. Grazing practices which appreciably damage or hinder other significant products or amenities of the forest will normally have to be curtailed. On the other hand, by recognizing improvements in several products of the forest, some very worthwhile management practices may become economically defendable that otherwise would not have been if only one product had been considered. An example of this is the benefit to range, water, **and** timber production which accrues from suitably thinning timber stands.

Physical Characteristics

Geographic

Ponderosa pine[2] dominates 3,657,600 acres or 92 percent of the State's commercial forest land (Spencer 1966). The ponderosa pine forest is for the most part equivalent to Merriam's Transition Life-Zone. The lower elevation is between 5,500 and 7,000 feet, and the upper elevation between 8,500 and 9,000 feet, varying according to slope and exposure. Pure stands occur most commonly between 7,000 and 8,000 feet.

[2] *Common and botanical names of plants mentioned are given at the end of this Paper.*

Ponderosa pine grows in many areas of the State, but the bulk of it is found in central Arizona where it occurs as an unbroken stand for nearly 225 miles (fig. 1). It is the major forest type that covers much of the Kaibab and Mogollon Plateaus. The Transition Zone is also the major forest life-zone on the higher conifer-clad mountains of the State. The southern conifer-clad mountain ranges are isolated with relatively steep topography when compared to the extensive mesas and plateaus to the north (Lowe 1964a).

Ninety-six percent of the commercial forest area is in other than private ownership. The 4 percent private ownership is the lowest proportion of any State except Alaska (Spencer 1966):

	Commercial forest area (*Thousand acres*)
National Forest	2,630
Indian	1,144
Bureau of Land Management	2
State	32
County and municipal	2
Farmer	82
Miscellaneous private	85
Total	3,977

Climatic

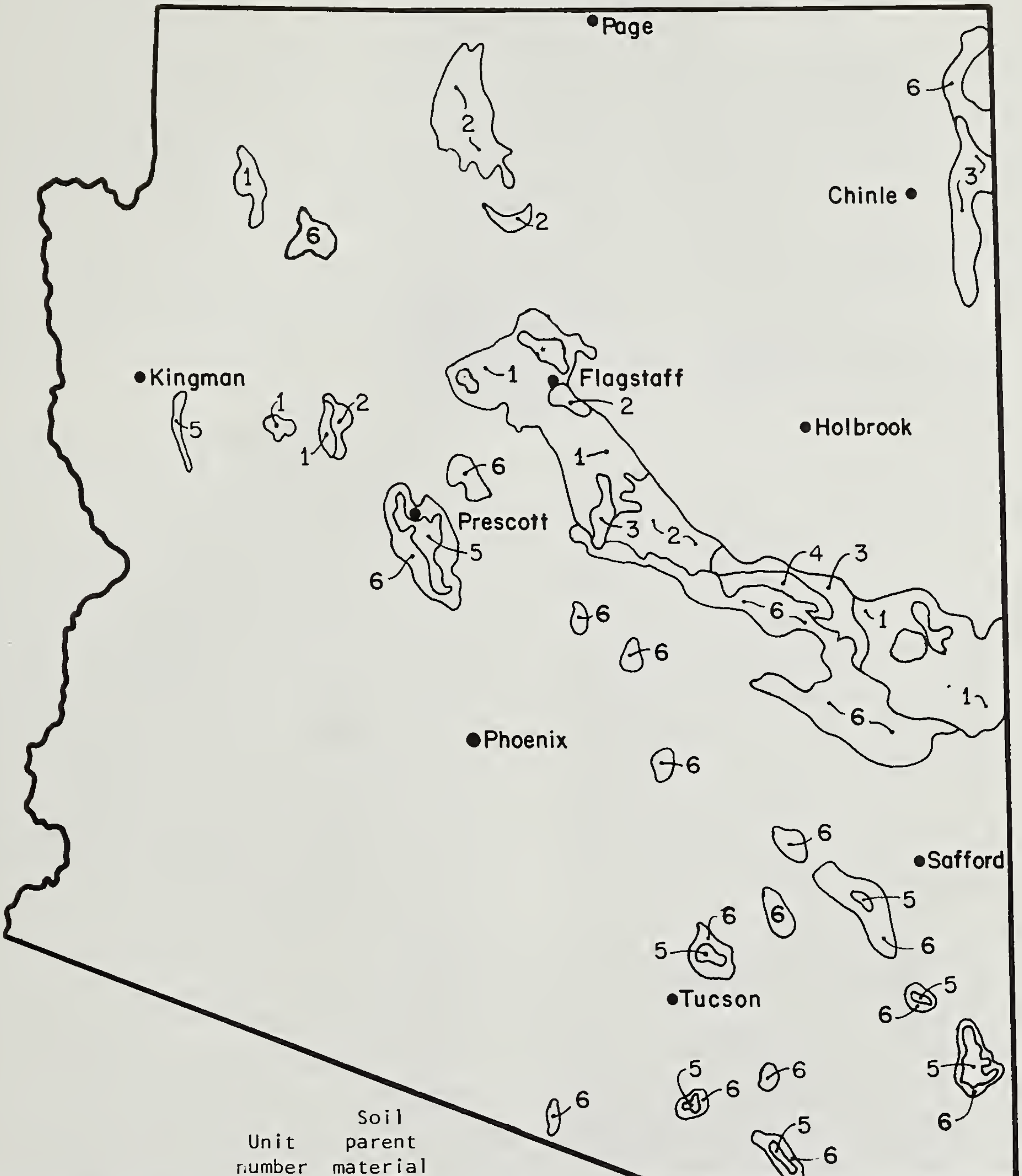
Southwestern ponderosa pine grows in a climatic zone where moisture is commonly in short supply. In Arizona, winds in the summer enter from the southeast, bearing moisture from the Gulf of Mexico (Kangieser 1966). The heaviest thundershowers usually occur in the mountainous region of central and southeastern Arizona.

Winter precipitation originates primarily from the Pacific Ocean (Kangieser 1966). These winter storms drop most of their moisture in the high mountains of the central and northern parts of the State. Snowfall may total 200 inches or more, but averages 12 to 94 inches.

Annual precipitation in the Arizona ponderosa pine type averages about 20 inches, with a number of areas exceeding 25 inches and some below 17 inches (Schubert 1974).

The climate in Arizona ponderosa pine differs from other interior ponderosa pine regions in that it has two pronounced precipitation periods (winter and summer). Ponderosa pine areas in eastern California and eastern Oregon have a general summer dry period with July and August being the driest; these are the wettest months in Arizona. In the Black Hills, the wettest months are May and June; these are the driest in Arizona (Pearson 1951).

Cold air masses from Canada at times cause temperatures to drop considerably below zero in the high plateaus and mountain regions of central and



	Unit number	Soil parent material
SOILS SUPPORTING PRIMARILY PONDEROSA PINE:	1	Basalt and cinders
	2	Limestone
	3	Sandstone
	4	Alluvium
	5	Granite and schist
SOILS SUPPORTING SOME PONDEROSA PINE:	6	Various parent materials

Figure 1.—Generalized soil groupings supporting ponderosa pine (interpreted after Buol 1966).

northern Arizona (Kangieser 1966). The lowest temperature recorded in the pine type in Arizona was -37°F at Fort Valley Experimental Forest near Flagstaff, on January 12, 1963, and at Maverick on January 13, 1963.

In the summer, afternoon temperatures may reach 80°F and higher, and then drop to 50°F or even down to 35° to 40°F at night. June, with few cloudy days, may have higher temperatures than July and August, which have afternoon convection storms that reduce solar radiation (Schubert 1974).

The average growing season, based on the last spring killing frost and the first in the fall, varies generally from 117 to 160 days, although extreme stations vary from 78 to 207.

Edaphic

Ponderosa pine occurs widely over soils developed from both igneous and sedimentary origin. Soil variations affecting distribution are more likely to be physical than chemical. Those factors affecting available moisture tend to be the most important (Pearson 1950). The more porous soils are the more productive, in general.

Conifer forests occupy many of the higher elevations of the State and, as previously noted, ponderosa pine dominates on over 90 percent. The soils supporting these conifer forests can be separated into two major groups: those that either (1) do or (2) do not have light-colored, leached upper horizons (Buol 1966). The first group of soils has developed principally from limestone, sandstone, and Tertiary-Quaternary gravel parent materials, while the second group has developed mainly from basalt and volcanic cinder parent material (fig. 1).

Forested soils developed on basalt and cinders in Arizona are typified by the Brolliar, Siesta, and Sponseller series. These have a dark brown to reddish-brown surface soil, 5 to 8 inches deep, which ranges in texture from clay loam to silt loam. The subsoil is usually clay textured and noncalcareous. These soils generally fall into the Typic Argiboroll category (Coconino National Forest data), although the soils in the warmer locations may be in the Udic Argiustoll category.

Forested soils developed on sedimentary formations in Arizona are typified by the Soldier and Hogg series (limestone), Wildcat and McVickers series (sandstone), and the Overgaard series (Tertiary alluvium). These soils typically have grayish-brown surface soils with sandy loam textures which may include some gravels or cobbles. An A_2 horizon several inches thick is present in the Overgaard soils. The subsoils are usually reddish-brown clays. These soils are generally Glossic, Mollic, Aquic, or Typic Eutroboralfs (Anderson et al. 1963, Buol 1966).

Other soils that support at least some ponderosa pine are primarily those on steep slopes where rapid geologic erosion has restricted profile development. These include: (1) higher elevation mesic soils developed from various parent materials, (2) shallow frigid soils developed from granite and schist, and (3) shallow frigid soils developed from volcanic materials that are located in the highest rainfall areas and are mainly vegetated by spruce and fir (Buol 1966).

Soils that typify grass parkland inclusions within the ponderosa pine elevational range are Friana (basalt parent material) and Clover Springs (limestone parent material). These are located on alluvial or depressionlike areas. The profiles tend to be heavier textured and deeper than upland soils formed from similar geologic formations. They are imperfectly drained and are classified as Typic Haplaquolls.

Ecological and Biological Characteristics

Flora and Fauna

The southwestern ponderosa pine type occurs mainly as a climax forest (Pearson and Marsh 1935) in pure irregular uneven-aged stands consisting of small even-aged groups varying in size from a few trees to several acres. This tendency toward small-even-aged groups is one of the main features of southwestern ponderosa pine forests. There are few acres in which the forests could be termed as all-aged, although there are many areas which contain stands in excess of 5 acres classified as even-aged. The irregularity in occurrence of the even-aged groups causes numerous small openings in the forest, which benefits the herbaceous plants and those consumers utilizing them.

There are several notable differences between the Transition Zone habitats of the southern mountains (south of the Salt River), and those to the north on the Colorado Plateau (Lowe 1964a). In central and northern Arizona north of the Mogollon Rim, the ponderosa forests usually contain few trees of other species, but they have a grass cover which often extends through parklike landscapes (fig. 2). On the few high mountains which rise abruptly from the Colorado Plateau, the ponderosa pine forest is present on rugged precipitous terrain more typical of the mountains in southern Arizona. The southern conifer-clad mountains are isolated ranges with relatively steep topography. These forests tend to have a complex composition of conifers and hardwoods, many of which have their areas of principal distribution in Mexico and reach their northern limits in Arizona south of the Mogollon Rim. Ponderosa pine parklands with well-developed grass areas and/or shrub understories, so typical of the north, are more often virtually nonexistent (Lowe 1964a).

Figure 2.—Open ponderosa pine-bunchgrass range.

Gambel oak is the most common tree associated with the pines (fig. 3), and quaking aspen may be scattered or may be in large stands on old burns, usually above 7,500 feet. In the lower part of the zone, below 7,000 to 7,500 feet, pinyon and juniper may be mingled with the pines; Douglas-fir is occasional to frequent above about 7,000 feet.

Understory shrubs, in climax stands, may be essentially lacking to fairly common, though more or less widely and irregularly spaced. Some may be locally abundant, particularly at lower elevations in the forest as seen on the South Rim of Grand Canyon and on the Navajo Indian Reservation. Among the shrubs which may be found in this northern Arizona forest are Fendler ceanothus, fernbush, fendlerella, wax currant, New-Mexican locust, blueberry elder, skunkbush sumac, greenleaf manzanita, Parry rabbitbrush, big sagebrush, black sagebrush, cliffrose, Apache-plume, mountainmahogany, and littleleaf mockorange. At high elevations, the shrubs of the pine forest are more commonly species shared with the fir and spruce-fir forest: snowberry, mountain ninebark, American red raspberry, rose, common juniper, bush rockspiraea, creeping mahonia, cliff Jamesia, and myrtle boxleaf.

Perennial forbs typical of the ponderosa pine more or less throughout the State are meadowrue, American vetch, Lambert crazyweed, and Louisiana wormwood. The genera of other common forbs are: lupine, peavine, cinquefoil, yarrow, goldenrod, paintbrush, penstemon, fleabane, deervetch, groundsel, hymenoxys, milkvetch, violet, bracken, globemallow, beebalm, iris, mullein, toadflax, mock-pennyroyal, golden-pea, and others.

Grasses characteristic of the northern Arizona ponderosa pine forests include Arizona fescue, mountain muhly, screwleaf muhly, pine dropseed, mountain brome, spike muhly, deergrass, prairie June-

Figure 3.—Gambel oak in a northern Arizona forest.

grass, bottlebrush squirreltail, Arizona threeawn, little bluestem, mutton bluegrass, blue grama, black dropseed, and Kentucky bluegrass (Lowe 1964a, and plant lists from Region 3, USDA-FS). *Carex* spp., mainly dryland sedges, are also present. Though common in the mountains of central and northern Arizona, Arizona fescue apparently is absent from the pine forests of the most southerly ranges. The most characteristic grasses there are two perennial muhlys, mountain and screwleaf muhly (Lowe 1964a). Descriptions and illustrations of the major forage species can be found in Judd (1962).

The herbaceous bunchgrass vegetation found beneath the tree canopy in the ponderosa pine forests also occurs in even greater densities in "parks" and "prairies" included within the elevational and geographic range of ponderosa pine (figs. 4 and 5). These openings in the forest constitute only a small portion of the total acreage within the pine type, but are locally important.

Comprehensive lists of vertebrates for the Arizona ponderosa pine type have apparently not been made, although a checklist for the entire State can be found in Lowe (1964b). Individual studies have provided information on the more common species. A description of the bird life present can be found in Carothers et al. (1973).

This vegetation type is probably best known for its populations of elk, mule deer, Merriam's turkey, and tassel-eared squirrels.

Successional Pattern

The successional pattern in Arizona ponderosa pine-bunchgrass ranges has been described (USDA-FS 1951, Arnold 1955). This pattern is typical of the major portion of the type, where ponderosa pine is virtually the only timber species present, few if any shrubs are present, and the herbaceous understory is dominated by bunchgrasses.

Deterioration from continued heavy grazing progresses through a series of stages because livestock grazing exerts a selective influence upon herbaceous plant communities. The prevailing plant life-forms of each of these successive stages of deterioration are progressively shorter lived. This sequence of life-forms (fig. 6) corresponds to the general plant strategies which provide adaptation to environmental stress and disturbance (Grime 1974). Grazing may completely denude local spots around corrals and watering places.

The following illustrates how prevailing plant life-forms (and typical species) reflect deterioration and recovery of vegetation in forest openings as livestock grazing pressure increases or decreases:

Successional stages in forest openings

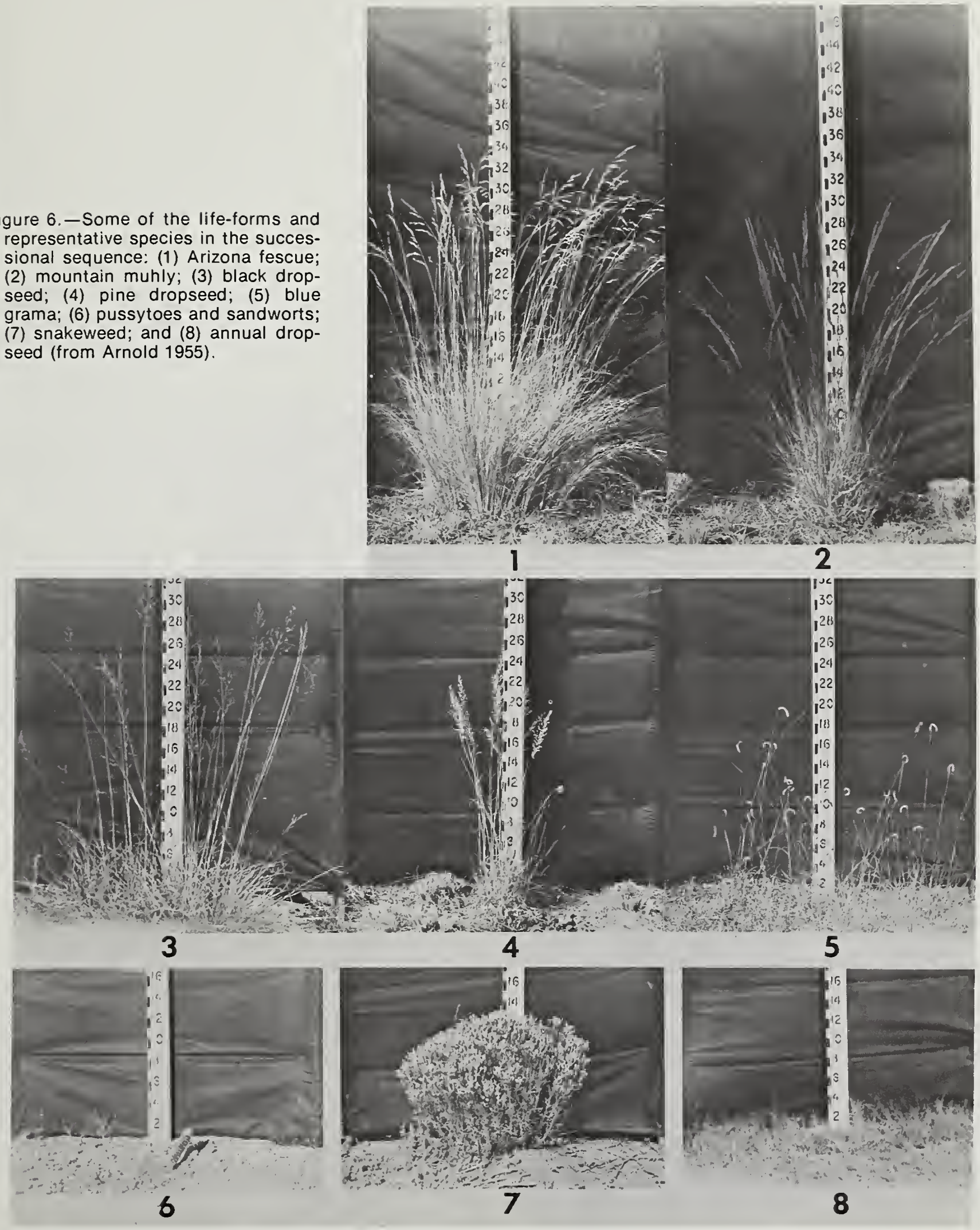
Recovery

Bunchgrass stage
↕ (Arizona fescue and mountain muhly, or screwleaf muhly)
Sod-forming grass stage
↕ (Black dropseed, Kentucky bluegrass, and blue grama)
Prostrate perennial forbs
↕ (Pussytoes and sandwort)
Short-lived half-shrub stage
↕ (Broom snakeweed and hymenoxys)
Annual stage
↕ (Annual dropseed)
Denuded soil stage

Figure 4.—Small park within a ponderosa pine forest.

Figure 5.—Government Prairie west of Flagstaff, Arizona.

Figure 6.—Some of the life-forms and representative species in the successional sequence: (1) Arizona fescue; (2) mountain muhly; (3) black dropseed; (4) pine dropseed; (5) blue grama; (6) pussytoes and sandworts; (7) snakeweed; and (8) annual dropseed (from Arnold 1955).



A detailed list of species and their approximate places in the successional sequence is available (USDA-FS 1969).

It should be noted that, even in the bunchgrass stage: (1) grass species which either escape or withstand a high degree of grazing abuse occur as components of the herbaceous composition; (2) perennial forbs occupy a small but constant part of the total herbaceous ground cover; and (3) annuals are generally rare except for years of abundant moisture (Arnold 1950).

The course of natural recovery may or may not retrace the course of deterioration. Under reduced stocking, recovery may retrace the stages of deterioration because grazing always has a selective influence upon the vegetation. Complete natural recovery of denuded areas may require over 100 years under reduced stocking, judging from a few denuded areas in northern Arizona where recovery has only reached the half-shrub stage after 30 years (fig. 7) (USDA-FS 1951). Recovery in response to protection from grazing need not progress through successive stages, because in the absence of selective grazing, perennial grasses may become reestablished simultaneously with various perennial forbs and half-shrubs. Similarly, ponderosa pine seedlings may become established during the early stages, and the forest opening can progress directly to a forested condition.

Forms of disturbance other than grazing which typically affect the vegetation are logging, fire, and attempts at dryland farming. Each type of disturbance has its own long-term effects on the creation or reduction of forest openings and the plants growing in these forest openings. A variation of the successional sequence previously described may result when the disturbance is mechanical in nature rather than by grazing stress. The early stages will often be dominated by such tall species as lambsquarters, mullein, and thistle (fig. 8).

Proportional densities of the various life-forms are directly related to ecological range conditions. High densities of tall grasses in mountain meadows and high densities of bunchgrasses in pine-bunchgrass openings indicate good to excellent range conditions. Poor and very poor range conditions are characterized by perennial prostrate forbs, short-lived half-shrubs, and annuals.

Figure 7.—Half-shrub successional stage in an area continuously grazed.

Figure 8.—Vigorous growth of pioneer species after mechanical disturbance.

Phenological Development

The phenology of the primary forage grasses of the Arizona ponderosa pine type—Arizona fescue and mountain muhly—were studied in 1963-65 (fig. 9). During this period Arizona fescue bloomed between August 2 and 19, while mountain muhly bloomed between September 7 and 25. Later information suggests that Arizona fescue may bloom nearly a month earlier than indicated above, if conditions are right. The rate of fescue growth from May through July is apparently related to precipitation falling in the prior month. Rate of muhly growth during July and August, however, appeared to be more closely related to the same month's precipitation.

Growth rate and final height of Arizona fescue are greatest in open areas, and decrease as the pine overstory increases. Mountain muhly growth rates apparently are not related to tree overstory (Pearson

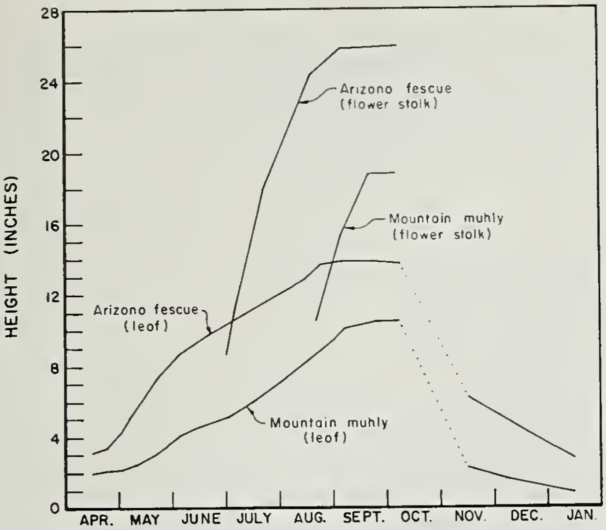


Figure 9.—Average heights of Arizona fescue and mountain muhly (after Pearson 1967b). Dashed lines indicate rapid drying.

1967b). Moisture competition is greater between fescue and ponderosa pine than between muhly and ponderosa pine (Pearson 1942).

Studies of bottlebrush squirreltail in a transplant garden at the lower edge of the ponderosa pine zone suggest considerable inherent differences in phenology. Collections from sites only 17 miles apart, growing under uniform conditions in the transplant garden, differed in average flowering dates by 44 days. Based on the phenologic responses of the various collections and on Hopkins Bioclimatic Law, it is estimated that native bottlebrush squirreltail will begin flowering, on the average, in early June at the bottom edge of the ponderosa pine type and in mid-July to early August in the middle and upper portions of the type. This particular pattern of blooming is the result of an interaction of hereditary adaptation, seasonal distribution of precipitation, and growing season length (Clary 1972).

Flowering dates for some of the forbs in the pine type are given in table 1.

Table 1.--Average initial flowering dates for some of the more abundant forbs on Wild Bill Range and Beaver Creek watershed

	1971		1972	
	Wild Bill	Beaver Creek	Wild Bill	Beaver Creek
Aster, showy	--	Sept. 27	--	Sept. 19
Bahia, ragleaf	Sept. 13	Sept. 13	Sept. 6	Sept. 6
Bluets, Wrights	July 6	June 21	June 27	June 27
Bundleflower, James	--	Aug. 30	--	--
Dandelion, common	April 24	April 12	April 4	March 22
Eriogonum, redroot	--	Aug. 30	--	Aug. 22
Eriogonum, sulfur	--	July 19	--	June 27
Fleabane *(Erigeron formosissimus)*	July 6	July 6	July 24	July 24
Fleabane *(E. schiedeanus)*	Sept. 16	--	Sept. 18	--
Fleabane, spreading	Aug. 16	June 7	June 27	June 27
Fleabane, trailing	May 24	May 10	May 16	May 16
Geranium, Fremont	July 19	July 19	July 24	July 11
Gilia, woody	--	Aug. 30	--	July 11
Goats-beard	July 6	July 6	June 27	June 27
Goldenrod, Missouri	Aug. 30	Aug. 2	Sept. 6	Aug. 22
Indigobush, white	--	June 21	--	--
Knotweed, prostrate	July 19	July 19	July 11	July 11
Lettuce, prickly	Sept. 13	Aug. 16	Sept. 6	Aug. 22
Milkvetch	June 21	April 12	June 12	April 18
Mullein, flannel	Aug. 16	Aug. 16	Aug. 6	Aug. 22
Pea, red-and-yellow	June 21	June 21	June 12	June 13
Phlox	--	May 10	--	March 22
Pussytoes, Rocky Mountain	June 7	June 7	May 31	May 16
Sagebrush, flat	Aug. 30	Sept. 13	Sept. 6	Sept. 6
Sweetclover, yellow	June 21	June 21	--	June 13
Thistle, Wheeler	Aug. 16	Aug. 16	July 24	Aug. 6
White-ragweed	--	June 7	--	June 27
Willowweed, autumn	--	June 7	--	--
Yarrow, western	Aug. 16	Aug. 16	July 24	July 24

Herbage Production

The total production of understory herbaceous plants in the ponderosa pine type varies with weather, soils, management history, and timber overstory density. The typical ponderosa pine stand in the Southwest has only 60 square feet of pine basal area per acre, perhaps 5 square feet of other tree basal area, and, depending upon the site, perhaps a few shrubs. Such an open stand allows 200 to 300 pounds per acre of herbaceous plants to be produced. Some areas have several times this density of trees, however, and produce little herbage.

Production values under Beaver Creek watershed (Brown et al. 1974) cutover stands, where basal areas per acre average 92 square feet for ponderosa pine, 18 for Gambel oak, and 5 for alligator juniper, are:

Species	Production (*Pounds per acre*)
Grasses and grasslike plants	
Bluegrass, mutton	23
Dropseed, black	10
Grama, blue	23
Sedge	6
Squirreltail, bottlebrush	46
Others	16
Forbs and half-shrubs	
Aster, showy	3
Fleabane, spreading	4
Fleabane, trailing	3
Goldeneye, showy	3
Ragweed, western	7
Sagebrush, flat	3
Snakeweed, broom	3
Others	32
Shrubs	
Locust, New-Mexican	3
Oak, Gambel	13
Total	198

On the Wild Bill range (Pearson 1964), typical unthinned forest stands averaged 120 square feet of basal area per acre of ponderosa pine. There were no other tree species present. Understory production on untreated areas averaged:

Species	Production (*Pounds per acre*)
Grasses and grasslike plants	
Dropseed, pine	3
Fescue, Arizona	32
Muhly, mountain	44
Sedge	11
Squirreltail, bottlebrush	10
Others	2
Forbs and half-shrubs	
Fleabane	2
Lupine	5
Others	10
Shrubs	
Ceanothus, Fendler	T
Total	119

Effect of overstory.—It is generally understood that, as forest density increases, the productivity of the herbaceous understory decreases. This inverse relationship has generally been shown to be curvilinear (Pearson 1964, Jameson 1967, Clary 1969), although Cooper (1960b) and Arnold (1950) reported linear relationships. The herbage yields on productive sites vary from 50 to 75 pounds per acre under dense timber (fig. 10) to 1,000 to 1,200 pounds per acre on moderately grazed open grasslands. Open grasslands and forest openings that have had little or no grazing may have yields of 1,400 pounds per acre (Arnold 1955). Yields of herbage from the less productive soils, however, may be only half of those described above (Arnold 1950, Clary et al. 1966).

Figure 10.—Little herbage is produced under dense ponderosa pine stands.

The impact of this herbage-timber relationship (fig. 11) has been strongly felt by range managers. The establishment and subsequent development of the prodigious 1919 seedling crop of ponderosa pine across much of northern Arizona has resulted in a continuous decline in herbage production independent of grazing effects (Arnold 1950).

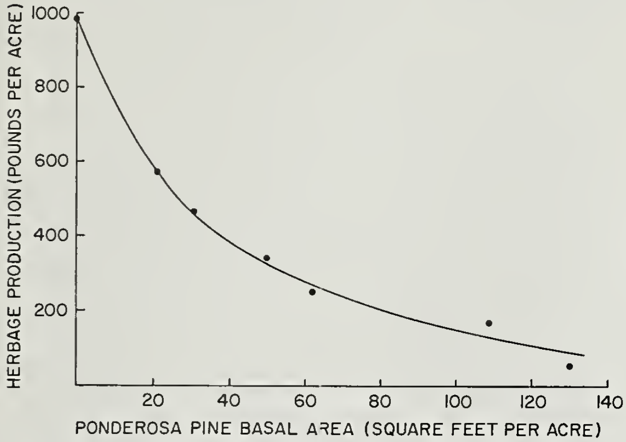


Figure 11.—Relation of herbage production to timber basal area on the Wild Bill range.

The relationship of herbage production to timber density is affected by timber management. Six years after thinning a ponderosa pine stand on the Beaver Creek watershed, herbage production under thinned stands was significantly greater than under unthinned stands for given timber basal areas of less than 70 square feet per acre (fig. 12). Similar results have been found on the Wild Bill range north of Flagstaff (Pearson 1967a). These thinning studies have indicated a rapid response of herbaceous vegetation to overstory reduction, although Arnold (1953) reports response may not always occur, particularly when the vegetation is suppressed by thick slash or heavy grazing. Reynolds (1962a) found the herbage production peaked about 6 years after logging, and suggested that production on selectively logged areas will exceed that of unlogged areas for 11 to 15 years.

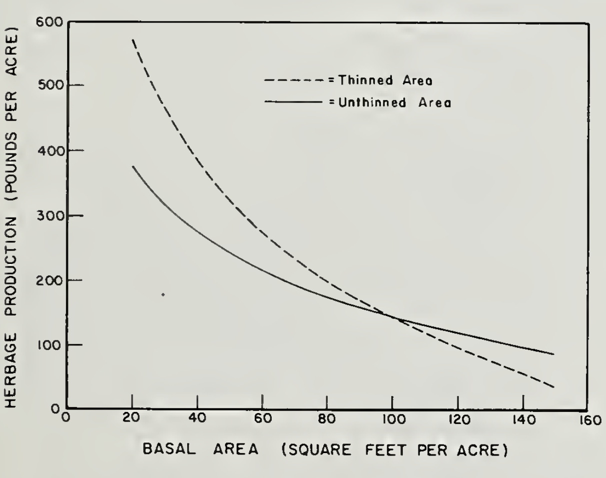


Figure 12.—Relationship between herbage production and timber basal area on thinned and unthinned areas (after Clary and Ffolliott 1966).

Effect of soils and weather.—In timber stands above 40 to 60 square feet of basal area, the production of herbage is similar on all soils, if the soils are developed from volcanic parent materials. However, where timber does not dominate the site, as in timber stands of very low density or in forest openings, large differences in herbage yields on different soils are possible (Arnold 1950, Clary et al. 1966). The more permeable of the volcanic-derived soils that produce the best timber are also capable of producing the most herbage.

Ffolliott and Clary (1975) show that understory-overstory relationships can differ under both high and low timber densities when soils differ greatly in parent material (volcanic versus sedimentary).

Little work has been completed concerning the effect of weather on herbage yields. A preliminary study has suggested a near linear increase in yields with increases in precipitation (Ffolliott and Clary 1974). Further work is needed however because, similar to the response to soils, the largest herbage response to annual weather differences will logically be where timber overstory dominance is minimum.

Effect of fire.—The proper place of fire in the southwestern ponderosa pine type has been the subject of considerable discussion. Pearson (1927) felt that the presence of fire-caused forest openings has resulted in timber production of half of the potential in some areas. Conversely, Weaver (1951) and Cooper (1960a) felt that periodic fires are a natural constituent of the southwestern ponderosa pine type, and have been important in developing and maintaining the "normal" stand structure of the type. They suggest that fire suppression, and to some extent overgrazing, have resulted in a timber stand structure dominated by young pine thickets. This change has reduced long-term timber and forage production.

We still need to learn much about the actual impact of fire on different forest values in the southwestern ponderosa pine type. Gaines et al. (1958) suggested that grass densities had recovered by the second year after a September controlled burn, but not after an October burn. Studies of the forest floor (Clary et al. 1968, Davis et al. 1968) suggest that fires must be sufficiently intense to modify the lower or H layer of the forest floor before herbage production will increase meaningfully.

A severe fire on the Wild Bill range crowned in a dense stand of ponderosa pines and essentially

eliminated the trees (Pearson et al. 1972). On an area thinned to 20 square feet basal area per acre, however, the fire remained on the ground and tree density was not significantly reduced. Herbage production increased as much as 1,000 pounds per acre where fire had killed the timber stand. Increases were small in the ground fire area.

Factors Influencing Livestock Production

Improving Forage Production

Range condition.—Results from the Beaver Creek watershed and the Wild Bill range suggest that herbage yields may be roughly similar for similar undisturbed sites even though plant composition varies. Thus, if nonforage species are present, less of the forage species will be produced.

When a range is in good condition, the floristic composition is relatively consistent throughout the stand, so production of palatable grasses will increase with decreasing timber density (fig. 13). However, if livestock have grazed forest openings excessively, range condition will be poor, and floristic composition will be variable. Much of the herbage production in the openings will consist of unpalatable species, and the few remaining bunchgrasses will likely be "hiding" in the dense timber (fig. 14).

Herbage production by **forage** plants differs greatly under different range condition classes (table 2). One major way of improving forage yields is to improve management so that the range condition trend is upward.

Control of undesirable plants.—Unpalatable and poisonous species are often directly removed from the range to allow more forage to grow. Minimal work has been done in Arizona on control of unwanted plants in the ponderosa pine type.

Colorado rubberweed, or pingue, is often a problem in the ponderosa pine type, both because of displacement of forage plants and because it is poisonous to sheep. This species can be controlled by 2 to 4 pounds per acre of an ester of 2,4-D or TBA (Johnsen 1962). The herbicides are apparently most effective when applied during rapid plant growth in the prebud stage, preferably when the soil is moist.

Broom snakeweed, often a pest plant in the ponderosa pine type, reduces grazing capacity and may cause poisoning loss. Early work on controlling this species was done in more arid vegetation types (Parker 1939b). Parker found that grubbing, mowing, burning (with a flame gun), and chlorate sprays were effective controls. Similar methods were suggested for other undesirable plants (Parker 1939a).

Applications of 2,4-D and 2,4,5-T reduced the production of broom snakeweed and Cooper actinea

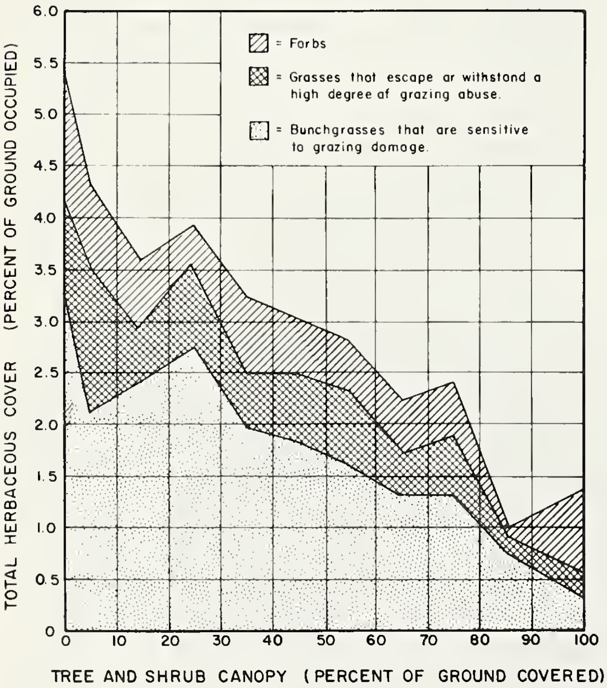


Figure 13.—The relationship between ungrazed herbaceous plant cover (in exclosures) and canopy classes of uneven-aged forest stands (after Arnold 1950).

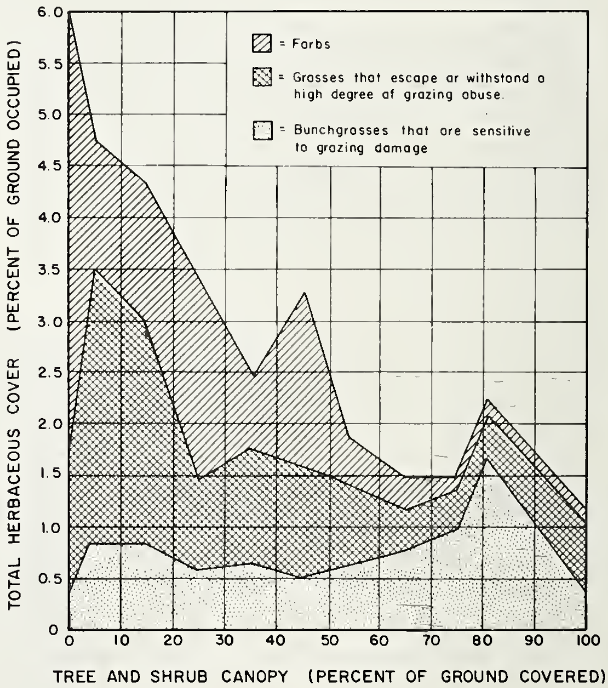


Figure 14.—The relationship between grazed herbaceous plant cover and canopy classes of uneven-aged stands (after Arnold 1950).

Table 2.--Relationships between cover and herbage yields of forage plants related to range condition classes (after Arnold 1955)

Type and condition	Cover (percent of basal line intercept)			Mean air-dry herbage yields of forage plants
	Bunchgrasses	Other herbaceous plants	Total	
		Percent		*Lb/acre*
Mountain meadows				
Excellent	10.59	2.87	13.46	6,351
Good	7.15	3.50	10.66	4,116
Fair	4.04	4.88	8.92	2,850
Poor	1.19	6.56	7.75	1,692
Very Poor	.02	6.64	6.66	1,374
Abandoned cropland	0	10.70	10.70	(1/)
Pine-bunchgrass openings				
Excellent	8.17	1.34	9.51	1,452
Good	5.45	2.53	7.98	988
Fair	2.48	6.25	8.73	699
Poor	1.35	7.77	9.12	518
Abandoned cropland	.02	2.52	2.54	(1/)

1/ Not sampled because areas were grazed at the time of observation.

by 90 and 60 percent, respectively, in north-central Arizona (Jameson 1966).

Gambel oak typically occurs in tree form in Arizona, and is not considered to be a significant range problem. However, control of the shrub form of Gambel oak may be required in some areas because: it can reduce forage yields, it can be a physical barrier to livestock movement, and it can cause livestock poisoning. On the Beaver Creek watershed, ammonium sulfamate crystals placed in trunk frills or girdles killed the tree crowns, but the base of the trees and the roots sprouted profusely. Dormant-season basal applications of 12 pounds per hundred gallons, acid equivalent, of an ester of 2,4,5-T in diesel oil killed many plants and repressed sprouts. Pelleted fenuron treatments also reduced sprouts (Johnsen et al. 1969).

Information from various sources on control of undesirable plants has been consolidated in the Nonstructural Range Improvements Handbook (USDA-FS 1970a) and the Guide to Improvement of Arizona Rangeland (Arizona Interagency Range Technical Sub-Committee 1973).

Because of changing regulations concerning pesticide use, current local, State, and Federal regulations should be checked before using chemicals to control undesirable plants.

Seeding.—Range seeding, properly done, can help improve forage production on many lands. Among the worthwhile reasons for reseeding are: to restore perennial grasses on ranges where they are now so scarce that natural recovery will take too long; to correct seasonal deficiencies in green forage; to provide special-use areas needed in a sound ranch management plan; and to prevent erosion where there is danger of soil loss (Reynolds et al. 1949).

Natural parks or openings, varying from 10 to 100 acres, are common throughout the ponderosa pine type. Many of them have been so disturbed by overgrazing or farming, that few perennial forage plants remain. These openings, along with areas disturbed by logging or fire, are good candidates for reseeding efforts.

The essential steps for successful reseeding are: (1) select productive sites, (2) remove competing vegetation, (3) plant suitable species, (4) use good seed, (5) observe proper rate and depth of planting, and (6) plant at the proper season (Reynolds et al. 1949).

When seeding deteriorated openings, return on investment will probably be greatest on level or gently sloping sites with fertile soil and good moisture conditions. Species seeded must not only be well adapted to the environment in which they are expected to grow, but they also must be suited to the purpose for which they are needed. Table 3 provides a good choice of species for meeting various requirements. These were the best adapted species out of over 170 that were tested under various conditions. Crested wheatgrass and intermediate wheatgrass have generally shown the widest range of adaptability, although once established, big bluegrass can produce outstanding yields (Lavin and Springfield 1955). In areas with annual precipitation above 25 inches,

orchardgrass, smooth brome, and tall oatgrass may produce a more palatable and nutritious forage (Reynolds et al. 1949).

The selection of species to be seeded should be based in part upon the period when they will be grazed. Livestock tend to prefer the species that are most succulent during the grazing period. For instance, orchardgrass, smooth brome, and slender wheatgrass are preferred over big bluegrass and the wheatgrasses for early fall grazing (Lavin and Springfield 1955).

Removal of competitive vegetation before seeding is essential for good results. Disk-type plows have generally proved best for preparing sites. They effectively remove competing vegetation without loosening the seedbed excessively. For best results the seed should be drilled rather than broadcast, unless the seedbed is well prepared.

Recommended seeding rates vary according to species from less than 1 pound to about 15 pounds per acre, but generally average 6 to 10 pounds of good quality seed. For the southwestern ponderosa pine zone, plantings made from about mid-June to mid-July, just prior to or at the beginning of the summer rains, have been most consistently successful (Lavin and Springfield 1955, USDA-FS 1970a).

Establishment of a grass stand is often necessary to retard erosion on recent burns and other timber lands disturbed by logging and other activities. Under these conditions there is usually a suitable seedbed and little competing vegetation, therefore broadcast seeding can be effective as well as economical. Drilling may be required on compacted areas such as logging roads.

On logging roads used intermittently and on drainageways, long-lived sod-forming grasses such as intermediate wheatgrass and smooth brome will give maximum protection. Where quick, but temporary, erosion control is needed until young pines become established, short-lived grasses (table 3), sweetclover, and annual mustards should be considered (Lavin and Springfield 1955).

New plantings need protection for at least the first two growing seasons so that the plants can develop enough root system and top growth to withstand grazing. Thereafter, the seeding should be grazed conservatively so forage production can be maintained.

Seeding is only one of the ways to improve rangelands. The possibilities of improving native range through better management should be carefully considered before attempting costly seeding work. Careful management is required to maintain forage production regardless of whether an area is seeded.

Additional detailed information on planting techniques and adapted species is available in two handbooks: Nonstructural Range Improvements Handbook (USDA-FS 1970a) and Guide to Improvement of Arizona Rangeland (Arizona Interagency Range Technical Sub-Committee 1973).

Table 3.--Relative success ratings of 23 species tested at 5 locations in ponderosa pine openings (after Lavin and Springfield 1955)

Species	Location and elevation (ft)				
	Jarita Mesa (8300)	Fort Valley (7400)	White Horse Lake (6900)	Peterson Flat (6500)	No Agua (8200)
	- - - Relative success[1] - - -				
LONG-LIVED GRASSES:					
Bluegrass, big	E	G	F	0	NT
Brome, smooth	G	G	G	P	NT
Orchardgrass	F	F	G	0	NT
Wheatgrasses--					
Beardless	G	G	F	F	F
Bluebunch	E	G	0	VP	NT
Western	F	E	E	G	NT
Crested	G	E	G	G	E
Intermediate	E	E	E	F	E
Pubescent	E	G	G	P	G
Tall	G	G	G	F	F
Wildrye, Russian	G	E	G	F	NT
SHORT-LIVED GRASSES:					
Brome, California	G	G	G	F	NT
Oatgrass, tall	G	G	G	F	NT
Rye--					
Mountain	E	E	G	G	NT
Winter	G	G	E	F	NT
Timothy	F	P	F	0	NT
Wheatgrass, slender	E	E	E	G	E
Wildrye--					
Blue	E	G	F	VP	NT
Canada	F	E	F	VP	NT
LEGUMES:					
Alfalfa--					
Grimm	F	F	G	P	NT
Ladak	F	F	G	F	NT
Sweetclover (biennial)--					
White	E	P	G	F	NT
Yellow	G	P	F	F	NT

[1]Relative success: E=Excellent; G=Good; F=Fair; P=Poor; VP= Very Poor; 0=Failure; NT=Not Tested.

Other techniques.—Forage yields can also be improved by fertilization and water spreading. There apparently has been little documentation of the effectiveness of these techniques in the Arizona ponderosa pine type.

A single fall fertilization of intermediate wheatgrass with nitrogen increased herbage production for 4 years (Lavin 1967). Over the 4-year period, nitrogen levels of 33, 66, and 99 pounds per acre produced 31, 35, and 27 pounds of dry matter per pound of nitrogen, respectively. Phosphorus fertilization had little effect on plant growth.

An indirect benefit of fertilizing is that cattle distribution can be manipulated because of the attraction of the animals to fertilized areas. Investments in fertilization should be approached carefully, however, as it is often questionable whether the increase in animal weight gain will be sufficient to justify the cost (Duvall 1970).

Nutritional Value of Forage Plants

Much of the nutritional information applicable to Arizona ponderosa pine ranges has been developed at

the Wild Bill range (Pearson 1964). Chemical constituents and digestibility of typical forages on ponderosa pine summer range have been related to timber overstory, season, species, and plant part.

Chemical constituents.—Chemical components of four forage species growing under various pine densities were analyzed to determine the effects of tree overstory (table 4). Crude protein content was higher in forages growing in the open than under a timber overstory. This trend was not apparent for phosphorus and ash content. Some differences in crude protein were apparent among species; crude protein content was greatest in bottlebrush squirreltail and least in mountain muhly.

Table 4.--Some chemical constituents of four forage species in the open and under a timber overstory[1] (Lines connect species that are not significantly different. Plants were significantly higher in crude protein in the open than under a tree cover.)

Constituent and overstory condition	Mountain Muhly	Arizona fescue	Dryland sedge	Bottlebrush squirreltail
	percent			
Crude protein				
Open	6.8	10.6	11.7	16.0
Timbered	6.1	7.5	9.5	9.7
Phosphorus				
Open	.20	.30	.22	.25
Timbered	.18	.24	.18	.26
Ash				
Open	8.4	10.2	10.6	12.3
Timbered	8.0	11.6	9.8	13.7

1/ Pearson, H. A. Personal communication.

Similar studies showed average seasonlong nutritional values did not differ greatly among heads, stems, and leaves of a plant.

Forage diet mixtures, as determined by paired plot techniques, showed a constant decline in crude protein content through the summer (from 12.5 percent in late June to 6.5 percent in late September). No seasonal trend in mineral content was apparent.

Digestibility.—The value of a forage species to a herbivore is largely related to its digestibility. In vitro forage digestibility studies (Pearson 1970) show that forages grown in the open are significantly more digestible than those grown under a timber overstory, although the differences are not large:

	Open	**Timbered**
	(Percent digestibility)	
Mountain muhly	50.9	47.6
Arizona fescue	57.4	51.6
Dryland sedge	58.6	54.6
Bottlebrush squirreltail	66.7	61.0

Heads and stems generally increased in digestibility from August to September, while leaves decreased. On the average, leaves were more digestible than stems and heads in August, and heads were more digestible in September (Pearson 1967c). When the herbage of two grass species was clipped and segregated into upper, middle, and lower segments (Pearson 1964), the herbage from the lower portions of the plants was less digestible.

Since cattle are selective grazers, the stage of plant development and nutritive value of plant parts will probably influence animal preference (Pearson 1967c). Livestock selectivity is demonstrated in some 1965 data. Digestibilities of composite cattle diets, as determined from paired plots, averaged 61.9, 54.1, and 51.4 percent for the periods June 19, August 10 to 13, and September 15 to 27, respectively. However, digestibilities of Arizona fescue and mountain muhly, the primary forage species present, averaged only 59.2, 46.5, and 44.5 percent for the same periods.

Effect of fire.—The effects of wildfire on subsequent forage quality are summarized in table 5. Crude protein, phosphorus, and in vitro digestibility were higher in the forages from the burned area the first growing season. Increases in digestibility and phosphorus content lasted through the second growing season.

Table 5.--Nutrient content of native forages on burned (B) and unburned (U) areas (after Pearson et al. 1972)

Date	In vitro digestibility		Crude protein		Phosphorus	
	B	U	B	U	B	U
	Percent					
1967:						
June	63.4	62.5	16.3	12.0	0.43	0.23
August	65.6	57.2	18.6	12.1	.39	.32
October	68.7	59.9	9.6	7.9	.27	.23
1968:						
July	65.2	62.0	9.2	10.0	.25	.22
August	61.1	53.6	9.5	9.8	.22	.21
September	51.3	50.1	9.6	9.6	.27	.22
1969:						
July	56.5	56.3	--	--	--	--

Livestock nutrition.—Nutritional levels of the typical summer range diet in Arizona ponderosa pine are generally adequate for yearlings (Halls 1970, Shepherd and Hughes 1970). Crude protein content does drop below required levels in late September, however. Seasonal intake of digestible protein and digestible energy also appears adequate (Howard 1971).

While ponderosa pine-bunchgrass forage meets minimum requirements for reasonable animal pro-

duction, it does not necessarily produce optimum animal gains. The possibility certainly exists for increased animal production in some areas through intensive management of pastures seeded to species of higher average nutritional levels, or to species that maintain adequate nutritional levels for a longer period of the year (Malechek 1966).

The only livestock supplement that appears to be needed on ponderosa pine summer range is salt. However, on those few allotments that are grazed yearlong or in winter only, protein and possibly phosphorus supplements may be needed to maintain adequate nutritional levels (Shepherd and Hughes 1970).

Deer nutrition.—Chemical analyses and in vitro digestibilities were made to determine the plants and plant parts important in the summer diet of deer in north-central Arizona (table 6). The nutritional quality of these summer diets appears to be quite good. Although a considerable variety of plants was available each month from May to September, Gambel oak leaves were rather consistently the predominant forage component in the summer diet.

Although few direct comparisons are possible, it appears that the diet selected by deer (the particular species and plant parts) may have higher nutritional value than the primary forage species consumed by cattle.

Table 6.--Chemical analyses and in vitro digestibility for some forage species consumed by deer[1]

Plant	Crude protein	Calcium	Phosphorus	In vitro digestibility
		-percent-		
Grasses				
Bluegrass	14	0.40	0.28	54
Bottlebrush squirreltail	12	.25	.30	52
Orchardgrass	19	.31	.38	60
Forbs				
Clover	28	.94	.42	70
Common dandelion	13	1.14	.41	54
Fleabane	10	1.04	.23	60
Geranium	10	1.08	.31	58
James bundleflower	15	1.07	.19	45
Peavine	24	1.17	.29	64
Red-and-yellow pea	15	1.32	.24	40
Redroot eriogonum	13	.77	.29	39
Slender milkvetch	20	.69	.25	70
Sweetclover vetch	24	.83	.36	63
Yellow sweetclover	21	1.28	.20	66
Browse				
Fendler ceanothus	18	.80	.26	52
Gambel oak	15	.58	.27	48
Ponderosa pine	7	.19	.14	41

[1]Urness, P. J., and J. R. Vahle, Rocky Mountain Forest and Range Experiment Station, and D. J. Neff, Arizona Game and Fish Department, personal communication.

Grazing Patterns and Forage Preferences

Grazing patterns.—Poor animal distribution may greatly reduce long-term animal production, and is a major contributor to range deterioration. Concentration of animals in the more productive forage sites often results in the decline or ultimate destruction of forage plants. Also, if the animals rarely graze the more inaccessible portions of the range, a portion of the animal production potential is never realized.

Ponderosa pine naturally grows in groups with scattered forest openings and open parks. The bunchgrass ranges are therefore often characterized by extremely uneven forage utilization (Glendening 1944). Grazing is normally most intense in forest openings or where the trees are scattered. Under heavy stocking, these openings can be grazed so severely that the bunchgrasses are completely eradicated, even though they reach their greatest abundance in the openings if protected from grazing. Conditions may decline to the point that the only bunchgrasses exist as isolated "islands" under dense timber (Arnold 1950). This condition of extreme overuse in the openings and underuse in the timber typifies many ponderosa pine ranges.

A number of factors influence the manner in which pine-bunchgrass ranges are grazed, when reasonably stocked with cattle. These include:

1. Distance from water (fig. 15).
2. Steepness and length of slope (fig. 16).
3. Trails and other access routes. These are important where timber or other natural barriers restrict animal movement.
4. Density of the timber stand. Utilization decreases as the forest density increases. Livestock seem to be attracted to forest openings and/or repelled by dense timber stands.

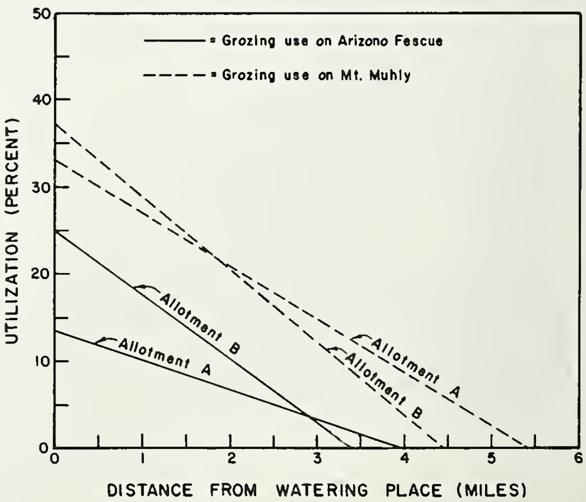


Figure 15.—Decrease in grazing use due to distance from water (after Glendening 1944).

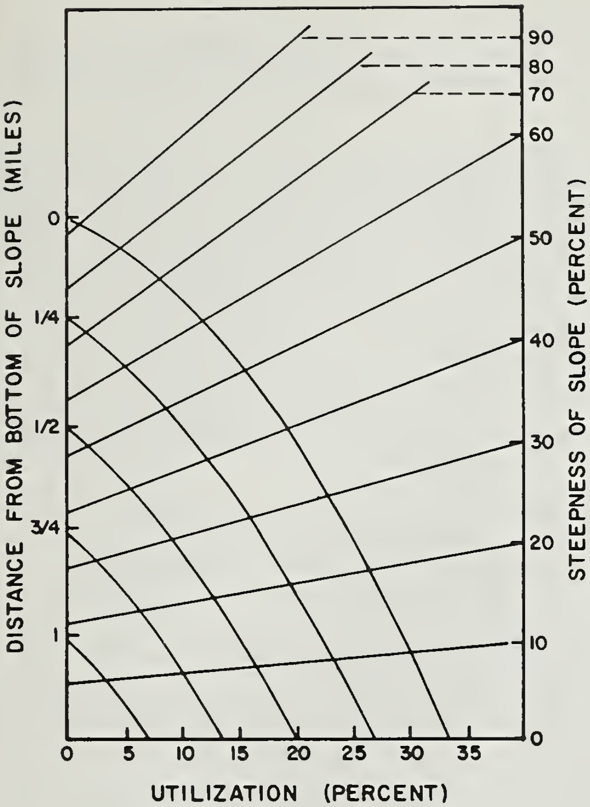


Figure 16.—Effect of steepness and distance from bottom of slope on percent grazing use of mountain muhly (after Glendening 1944).

5. Floristic composition and season of use. Arizona fescue is grazed most heavily in early summer, but the remainder of a summer growing season mountain muhly receives the heavier use. Grazing use of Arizona fescue decreases with increased abundance of mountain muhly.
6. Range condition. Ranges in poor condition, whether caused by overgrazing (usually more accessible), or fire or mechanical damage (remaining plants are often more succulent), tend to be closely grazed year after year, so that improvement in plant cover is prevented (Glendening 1944).

Forage preferences.—Glendening (1944) referred to the effect of floristic or plant composition on the response by grazing animals. A study of relative cattle preference for various forage species in northern Arizona (Clary and Pearson 1969) showed Kentucky bluegrass, Arizona fescue, and mountain muhly were most preferred under summer-long grazing, while blue grama and prairie Junegrass were least preferred. The following preferences are utilization percentages when associated bottlebrush squirreltail was grazed 20 percent:

Species	Preference (*Percent utilization*)
Kentucky bluegrass	39
Arizona fescue	33
Mountain muhly	31
Black dropseed	28
Sedge	24
Mutton bluegrass	23
Bottlebrush squirreltail	20
Blue grama	17
Prairie Junegrass	13

Because cattle spend more time grazing where forage is more abundant, species that tend to occur in areas of greatest accessibility may tend to be more prominent in the diet. This appears to be the case at the Wild Bill range. A diet preference rating was calculated as the ratio—Percent of species in diet:Percent of species in floristic composition. Ratios for pine dropseed, mutton bluegrass, bottlebrush squirreltail, and dryland sedge all indicated greater relative use than Arizona fescue and mountain muhly.

In a study of cattle preference for seeded grasses, orchardgrass, smooth brome, and slender wheatgrass were most preferred; crested wheatgrass, Kentucky bluegrass, and tall oatgrass were intermediate in preference; while western wheatgrass and big bluegrass were least preferred (Springfield and Reynolds 1951).

Animal preferences vary among forage species during a grazing season. The animals usually exhibit the greatest preference for a given species when it is growing rapidly, and when its succulence and digestibility are high (Springfield and Reynolds 1951, Pearson 1967c).

Range Condition, Grazing Systems, and Degree of Use

Range condition.—Range condition is a measure of the health of the range, based on what that range is naturally capable of producing. Range condition classes are a series of arbitrary categories used to classify range condition, which is usually expressed as either excellent, good, fair, or poor. Range condition trend is the direction of change in range and soil condition (Am. Soc. Range Manage. 1964).

Numerous systems have been developed for detecting range condition and trend. The 3-step method was adopted by the USDA Forest Service in 1956 (Parker and Harris 1959). Later studies determined, however, that accurate trend interpretation from conventional 3-step data is much more difficult and complex than originally hoped (Reppert and Francis 1973). In addition, loop-frequency has little consistent relationship to plant cover, herbage pro-

duction, or plant density (Francis et al. 1972). Thus, although the 3-step system with its range condition scorecards is still in use, the hoped-for simultaneous attributes of simplicity and maximum usable information are yet to be achieved. The Southwestern Region of the Forest Service has modified the 3-step method to include additional information on plant composition (USDA-FS 1970c). This modification provides a stronger data base, although it does not change the basic system.

The guidelines given by Arnold (1950) provide a good general direction for judging range condition, particularly as it is affected by grazing:

A. Do not confuse the reduction of forage production by thickening of the timber stand with that caused by improper livestock management. Increasing timber density has little effect upon the herbaceous floristic composition, but grazing does.
B. Unsatisfactory range condition is indicated by:
    1. A scarcity of bunchgrasses (Arizona fescue, mountain muhly, screwleaf muhly, and mutton bluegrass).
    2. A replacement of bunchgrasses with perennial grasses that escape or withstand a high degree of grazing abuse (blue grama, bottlebrush squirreltail, black dropseed, Fendler threeawn, and Arizona threeawn).
    3. A marked replacement of all perennial grass species by perennial forbs.
    4. An abundance of annuals.
    5. The survival of remnant bunchgrass "islands" under scattered trees. (See also earlier section on Successional Pattern.)

Ranges in top condition are desirable not only from an ecological standpoint, but also from a practical standpoint. Ranges in good to excellent condition can be expected to produce several times more palatable forage than does a range in poor condition (Arnold 1955).

Grazing systems.—The value of specialized grazing systems has recently been reviewed by Driscoll (1967), Shiflet and Heady (1971), Hickey (n.d.), and Martin and Cable (1974). The results of applying specialized (usually some type of rotation) grazing systems vary greatly from case to case. Sometimes the forage crop is benefited, sometimes the livestock, sometimes both, and sometimes neither. While specialized grazing systems are usually somewhat beneficial, they also have some drawbacks. Some advantages of rotational grazing systems are that they:

1. Provide periodic deferment or rest to allow desirable forage species to regain vigor.
2. Provide more complete use of the forage resource through better livestock distribution. Livestock also exhibit less plant selectivity within and between forage species.
3. Allow for the integration of seeding and control of undesirable species into the grazing plan without additional fencing for grazing control.

The primary disadvantages are the expense, mainly the development of additional livestock water and fencing, and in some cases depressed livestock gains. Gains may be less if cattle must eat less nutritious forage during some parts of the season, or are disturbed by frequent moving (Driscoll 1967).

No one system is best for all conditions; the system used should be tailored to each particular situation. The optimum system may even differ on the same grazing allotment as range condition changes. Major points to consider in selecting a grazing system for a particular allotment include:

- Kind and class of animal to be grazed.
- Kind and amount of vegetation.
- Amount and seasonal occurrence of rainfall.
- Topography and elevation.
- Length of growing season.
- Kind and characteristics of soil.
- Range condition and trend.
- Availability of funds for fencing, water development, and other range improvements.
- The needs of the livestock operator.

Grazing systems generally used on USDA Forest Service allotments in Arizona ponderosa pine include:

- Continuous.
- Rotation (two to four or more units).
- Deferred.
- Rest-rotation.
- Deferred-rotation.

Documented results are lacking as to which, if any, of the specialized grazing systems will produce optimum results. Systems recommended for semidesert grass-shrub ranges (Martin and Cable 1974) may not be directly applicable in the ponderosa pine type. Experienced range managers in Region 3 of the USDA Forest Service believe, however, that definite benefits have accrued on forested ranges from rest-rotation and deferred rotation systems under proper stocking. Pearson et al. (1971) reported a successful three-pasture rest-rotation system implemented in the Arizona ponderosa pine type. The system was designed to fit cool- and warm-season species growing in response to Arizona's distinct summer and winter precipitation periods. Documentation of plant and animal response was minimal, however.

Rotational grazing systems are probably the most effective in improving range condition when (1) site differences within range units are large and distribution is a problem, and (2) major forage species differ greatly in growth timing, life-form, or palatability.

The first requirements of any system of grazing, however, are proper use of the forage crop and uniform distribution of the grazing animals (Shiflet and Heady 1971).

Degree of use.—Little, if any, recent work has been documented on the proper amount of grazing use for the forage species on Arizona ponderosa pine ranges. Crafts (1937) suggested these utilization standards to alleviate livestock browsing on pine reproduction:

	Utilization (*Percent*)	**Minimum leaf stubble height** (*Inches*)
End of spring drought (July)		Within 1½
Arizona fescue	15	inches of
Mountain muhly	10-15	ungrazed areas
End of season (Oct.)		
Arizona fescue	35-40	6
Mountain muhly	45	4

Later guides were a bit more conservative (table 7).

Table 7.--Utilization standards for forage species on Arizona ponderosa pine ranges (from Parker 1942)

Species	Normal range		Steep slopes or deteriorated ranges	
	Stubble height	Volume removed	Stubble height	Volume removed
	Inches	*Percent*	*Inches*	*Percent*
Arizona fescue	6.0	25	8.5	15
Black dropseed	--	40	--	25
Bottlebrush squirreltail	4.0	40	5.0	30
Kentucky bluegrass	1.5	50	--	40
Mountain muhly	4.0	30	8.0	15
Pine dropseed	2.5	50	3.5	30
Prairie Junegrass	2.0	40	3.0	30

The "proper use factor" of 30 to 40 percent, often used on USDA Forest Service allotments, appears to be about right, although no definitive studies have been made.

Grazed-class photo guides (Schmutz 1971) and grazed-plant methods (Springfield and Peterson 1964) are useful in estimating the degree of utilization for several major forage species. Production-utilization methods now employed on the Southwestern National Forests (USDA-FS 1970c) use ocular estimates and mapping techniques. These methods provide weighted utilization means and mapped utilization distribution, which are quite useful in allotment management.

Beef Gains

Related to nutrient consumption.—Consumption of nutritious forage makes animal production possible. One of the best methods of assessing range value is by estimating potential animal gains based on forage intake and digestibility (Pearson 1972). Since forages can differ in nutritive value from year to year on various ranges, the digestibility measurements enhance forage evaluations. Forages from different ranges can then be compared, regardless of species composition.

A relationship has been developed that provides predictions of beef yields per acre for yearling heifers grazing southwestern ponderosa pine summer range (fig. 17). Information on consumption can be combined with data on digestibility to provide estimates of livestock production potential. This relationship was developed under conditions in which average utilization generally did not exceed 40 percent.

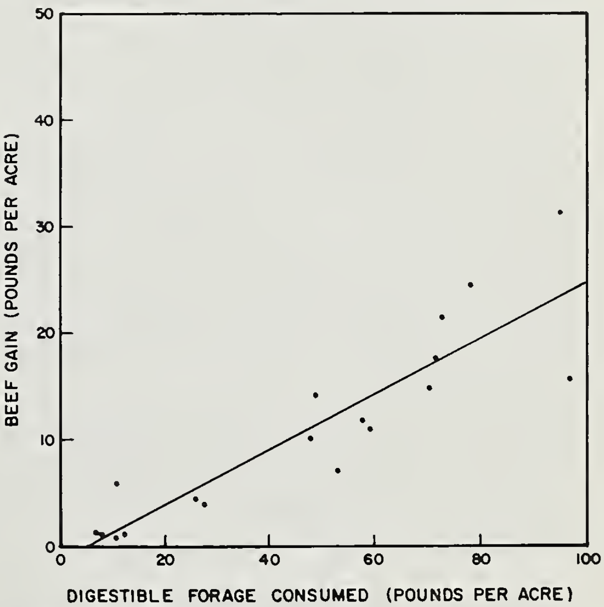


Figure 17.—Relationship between digestible forage consumed and beef gain per acre (after Pearson 1972).

An equation based on total dry matter consumption, instead of digestible dry matter consumption, was slightly less effective as a predictor of beef gains, but requires less data. The equation is: $G = 0.141C - 0.643$; where G = pounds of gain per acre, and C = pounds of dry matter consumed per acre (Pearson 1972).

The effect of forage digestibility on animal performance was demonstrated near Flagstaff, Arizona. Two groups of yearling steers from the same herd were grazed on ponderosa pine summer ranges about 30 miles apart and at about 500 feet difference in elevation. Digestibility of the diet components from the south range was 64.1 percent, while from the north range the average was 53.2 percent. Cattle gains were estimated to be 1.84 and 1.51 pounds per day, respectively, based on the assumption of similar forage intake on the south and north ranges (Henry

A. Pearson, formerly with Rocky Mountain Forest and Range Experiment Station, personal communication). These estimates compare favorably with actual gains of 1.92 and 1.45 pounds per day, and illustrate the differences in animal performance that can be expected due to forage digestibility.

A larger variety of forage species apparently provides more choice for the grazing animals, and they can select more nutritious diets.

Related to timber density.—Animal production per acre is greatly increased by reductions in the timber overstory, primarily through an increase in the forage supply. Other benefits include improved livestock distribution and perhaps a slight increase in forage quality. The relationship between tree density and beef gains per acre has been determined on the Wild Bill range with data from 1965 to 1971. These data were developed from range units thinned to various levels of tree density and grazed over a 4-month season at levels generally not exceeding 40 percent use. The relationship of beef gain to timber basal area (fig. 18) closely follows that of herbage yield to timber basal area. This indicates that, when livestock are well distributed, potential animal production increases roughly in proportion to an increase in forage supply. The maximum indicated potential beef gain is about 30 to 35 pounds per acre per year with complete timber overstory removal. Livestock production approaches zero under high-density ponderosa pine stands.

Physical relationships between beef and wood production and 1972 unit prices suggest that the combined economic value of grazing and saw-log production would be maximum in tree stands having a basal area of about 45 to 60 square feet per acre (Clary et al. 1975).

Related to use.—Animal performance on the Wild Bill range was affected by grazing intensity. Average daily gain per animal declined as percent utilization increased:

Utilization (*Percent*)	Daily Gain (*Pounds*)
≤ 25	1.42
26-50	1.28
≥ 51	1.12

Management of Livestock to Avoid Losses from Poisonous Plants

Nearly all poisonous plants are unpalatable, and cattle eat them only when forced by hunger or when mineral deficiencies result in depraved appetites. Animals normally vary their diet, and with adequate forage will seldom consume hazardous amounts of any one species of poisonous plant. Also, the presence of vigorous forage plants tends to inhibit the invasion and growth of poisonous plants. Thus good range management is the most practical and effective means of reducing long-term livestock losses due to poisoning on rangelands. Management techniques useful in reducing short-term poisoning losses include:

1. Feed mineral supplements (especially salt and phosphorus) to alleviate depraved appetites.
2. Use supplemental feed if the forage supply is short during critical periods.
3. Choose a season when the plants are less toxic or when toxic plants are less palatable.
4. Change to a kind of livestock that is less susceptible to the particular plant poison.
5. Keep livestock away from poisonous plant concentrations by riding, herding, salting, or fencing (Parker 1939c).

Poisonous plants in the Arizona ponderosa pine type, as taken from Schmutz et al. (1968), are:

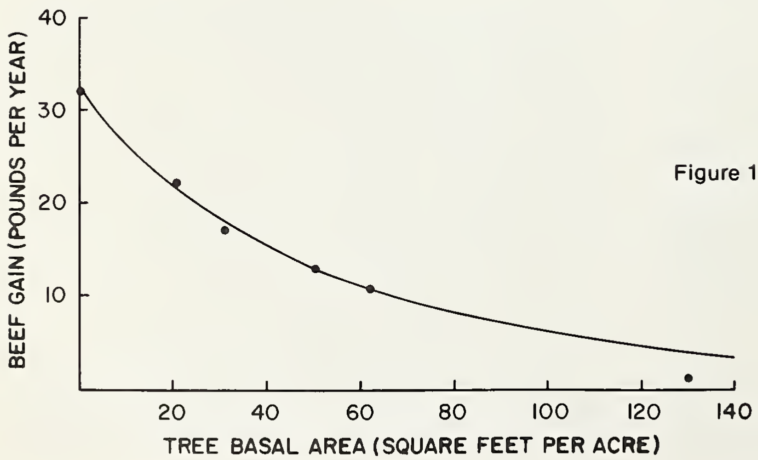


Figure 18.—Relationship of beef gain to tree basal area (after Clary et al. 1975).

Major poisonous plants

Cocklebur	Pingue
Douglas water-hemlock	Russianthistle
Larkspur	Snakeweed
Locoweed	Threadleaf groundsel
Mountainmahogany (?)	Whorled milkweed
Paperflower	

Secondary poisonous plants

Annual goldeneye	Gray horsebrush
Bracken	Horsetail
Chokecherry	Lupine
Cloakfern	Ponderosa pine
Coulter conyza	Sacred datura
Cutleaf nightshade	Spreading dogbane (Indian hemp)
Deathcamas	Spurge
Ergot	Tansy-mustard
False-hellebore	Western monkshood
Filaree	Western sneezeweed
Gambel oak	
Golden corydalis	

Grazing History, Current Conditions, and Allotment Needs

Stocking Rates and Carrying Capacities

Grazing use of the Arizona ponderosa pine type, and indeed all of the western ranges (Dutton 1953), has varied considerably over the past 100 years. Livestock numbers and degree of use were quite high from the late 1800's until the end of World War I (Seltzer and Pfuehler 1959). Thereafter, stock numbers declined as range abuse became widely recognized (fig. 19).

On those Arizona National Forest allotments that are 75 percent or more in the ponderosa pine type, approximately 15,000 permitted cattle (fig. 20) are grazed for a total of 80,000 animal-unit months (AUM) (based on 1973 allotment data from Region 3, USDA-FS). There were no sheep or dual use permits among the allotments meeting the 75 percent criteria.

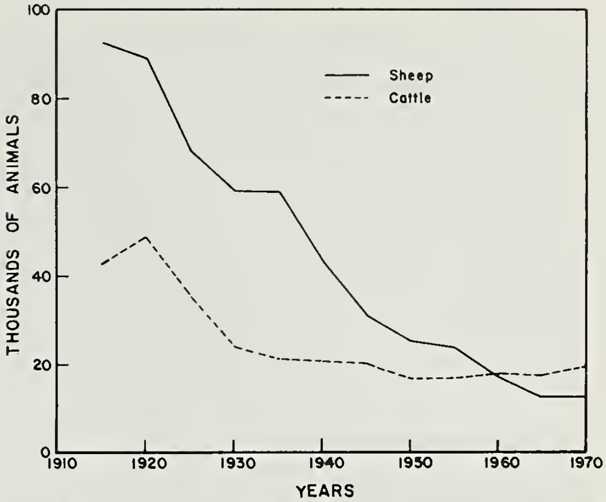


Figure 19.—Numbers of cattle and sheep grazed on the Coconino National Forest.

Potential carrying capacities of Arizona ponderosa pine rangelands have been estimated at 5 to 8 acres per AUM (Cooper 1959, Reynolds 1962b, Pase 1966). Actual grazing capacities vary considerably, generally in direct proportion to the forage supply. Production of herbaceous plants is strongly influenced by woody overstory, soils, and weather. Plant composition, vigor, and other factors that combine to describe "range condition" also greatly affect grazing capacities.

The average estimated grazing capacities and distribution of Arizona ponderosa pine ranges on National Forest land, by condition class, are:

Condition class	**Grazing capacity** (*Acres/AUM*)	**Distribution** (*Percent*)
Excellent	insufficient data	1
Good	7	6
Fair	10	48
Poor	18	40
Very poor	41+	5


Figure 20.—Beef cattle are the major domestic livestock.

These differences illustrate the tremendous impact of range condition on grazing capacities, especially when we consider that 45 percent of the ponderosa pine rangeland is in unsatisfactory condition (USDA-FS 1973).

The average estimated proper stocking rates for the different National Forests in Arizona are:

	(Acres/AUM)
Apache-Sitgreaves	12.0
Coconino	10.3
Kaibab	12.0
Tonto	31.5

Season of Grazing

A large portion of the Arizona ponderosa pine is grazed in summer only. Generally, this vegetation type is not suited to yearlong or winter use because of cold temperatures and deep snow. Acreages grazed in summer only average 87 percent for the Apache-Sitgreaves and Coconino National Forests, which have the largest ponderosa pine acreages of the Arizona Forests. The yearlong allotments tend to be in the more southern portion of the ponderosa pine type. Across the State the averages for the ponderosa pine type are:

	(Percent)
Yearlong	16
Summer only (generally May 1-Oct. 31)	79
Winter only (generally Nov. 1-Apr. 30)	3
Not indicated	2

Grazing Systems

In the early days, continuous grazing by excessive numbers of livestock, often coupled with poor distribution, resulted in many areas being totally "grazed out." Often, little recovery is evident 50 years later.

Considerable progress has been made in water developments, fencing, and so forth, to improve animal distribution. Various kinds of grazing systems have been applied to National Forest allotments.

The distribution of acreage, under broad classes of grazing systems, is:

	(Percent)
Continuous	9
Rotation	15
Deferred	19
Rest-rotation	42
Deferred-rotation	11
Not indicated	4

Thus, a high proportion of the ponderosa pine allotment acreage is currently under some type of an improved grazing system.

The existence of an "improved" grazing system on paper will accomplish nothing unless it is conscientiously applied on the ground. Even those so applied need to be examined periodically and modifications made if needed.

Some Immediate Allotment Needs

Even though the use of improved grazing systems is widespread on the National Forests, and even though livestock numbers are considerably below the numbers of the earlier, abusive years, only 55 percent of the ponderosa pine allotment acreage is in satisfactory condition. Obviously, considerable additional range improvement needs to be done.

"The first requirement of any so-called system of grazing . . . is still proper use of the forage crop and the uniform distribution of the grazing animals" (Shiflet and Heady 1971). An allotment needs first of all to be stocked commensurate with the forage supply available. In 1973, Arizona ponderosa pine ranges were being subjected to 35 percent more AUMs of grazing than was estimated to be proper (based on data from Region 3, USDA-FS). Carrying capacity estimates will likely change of course, as other changes are made in grazing management.

Uniform distribution of grazing animals is another important major requirement. When common range management practices are coordinated so as to complement each other, many grazing distribution problems are alleviated or prevented (Driscoll 1967). These practices include salting, supplying water, fencing, trail construction, and range riding or herding. While little or no work has been done in Arizona ponderosa pine to quantify the effects of these practices, experiences by livestock producers and public land managers have verified their benefits, especially the development of stock watering facilities. Pearson et al. (1969) described a trick tank design which provides a water supply more cheaply than hauling for those areas where other types of water supplies are not available.

Specialized grazing systems (usually some combination of rotation and deferment) also help alleviate the distribution problem. The cross fencing usually needed with specialized systems provides more control over the animals, and higher animal densities over shorter periods of time cause the livestock to graze less accessible portions of the range unit which they would not otherwise graze. They also graze more of the less palatable species and are less selective in grazing individual plants of the same species. The major advantage of a specialized system, especially if it includes deferment or rest, is that it allows preferred forage plants to recover on those areas which tend to be repeatedly or continuously grazed.

Costs and Returns

Range Improvement Practices and Grazing Intensity

There is very little substantial data concerning costs and returns of livestock operations specifically applicable to Arizona ponderosa pine ranges. Information from various areas will be utilized here in an attempt to develop an idea of economics involved in range livestock operations.

A recent study in the chaparral type of Arizona suggests that the marginal value of an additional AUM of grazing capacity (in 1972) is $5.82, or $70 per animal unit per year (O'Connell and Boster 1974). This animal unit has a current capitalized value of $1,000 at 7 percent interest (Water Resource Council 1973). Thus, to be economically feasible, the cost of a range improvement practice which adds one AU of grazing capacity should not exceed $1,000 total for both the initial improvement and all discounted maintenance expenses. Some typical expenses for the ponderosa pine type in general (Duran and Kaiser 1972) are given in table 8.

In the case of range fertilization, if we use Lavin's (1967) results of a 4-year response to fertilization which resulted in about a 2,300-pound-per-acre cumulative increase in forage production, the value of the increased carrying capacity, even without discounting, may be worth little more than two-thirds of the initial $12 per acre expense.

$$\text{Value} = \frac{(2{,}300 \text{ lb.})\ (50\% \text{ use})\ (\$5.82)}{750 \text{ lb. intake/AUM}} = \$8.92$$

Assume in the case of seeding, that the practice is applied to a totally depleted area with no current grazing capacity. Lavin and Springfield (1955) suggest a carrying capacity of 3 acres per AUM from successful seedings. Since **successful** seedings require seedbed preparation, the initial investment would be $60 per AUM of increased carrying capacity (3 acres x $20 per acre) (Duran and Kaiser 1972). Assuming the new stand is protected from grazing for 2 years and maintains maximum production for the next 28 years, the present value of the stream of benefits from the increased carrying capacity is also approximately $60. Thus, from a beef production standpoint, the cost of seeding will at best be just returned with little real profit.

Each potential range improvement practice needs to be carefully evaluated in each management situation. Many improvement practice-management situation combinations are not economically feasible from the standpoint of beef production alone. Other considerations, however, may justify such practices (USDA-FS 1970b, Smith and Martin 1972).

The grazing intensity that brings the greatest net revenue varies somewhat from situation to situation. Results from Colorado ponderosa pine ranges (Johnson 1953, Smith 1967) suggest that grazing at 30 to 40 percent utilization provides the greatest net revenue. Returns from Arizona semiarid grasslands were greater when they were grazed at 40 to 50 percent utilization than at 70 to 80 percent (Ariz. Inter-Agency Range Comm. 1972).

An equation has been developed (Pearson 1973) for estimating the degree of forage utilization that will

Table 8.--Some costs and expected life of range management practices in the ponderosa pine type of western United States (Duran and Kaiser 1972)

Management practice	Unit	Labor: Skilled	Labor: Unskilled	Equipment and material	Total costs	Expected life of practices[1]
						(years)
Fertilization	Acre	$ 1.00	$ --	$ 11.00	$	[2]1
Brush control:	Acre					
Mechanical		3.50	1.00	10.50	15.00	8
Chemical		1.00	.25	4.75	6.00	8
Fire		1.00	5.50	1.50	8.00	8
Debris disposal	Acre	2.00	3.50	2.50	8.00	30
Undesirable forb control	Acre	2.00	--	9.00	11.00	15
Mechanical soil treatments	Acre	3.00	.50	8.50	12.00	25
Seeding	Acre	1.50	.50	6.00	8.00	30
Prescribed burn	Acre	.75	3.50	1.25	5.50	5
Rodent control	Acre	.50	--	3.00	3.50	30
Insect and disease control	Acre	.50	--	1.00	1.50	20
Water developments:	Each					
Small		175.00	75.00	350.00	600.00	25
Large		300.00	650.00	850.00	1,800.00	30
Fences	Mile	300.00	1,000.00	700.00	2,000.00	30
Timber thinning	Acre	21.00	1.50	2.50	25.00	30

[1]Time until need reappears.
[2]Response lasted 4 years in Lavin's (1967) study.

·yield maximum profit. Factors included are cost per animal day, revenue per pound of beef, gain per animal day, digestible forage consumed per acre, and digestible forage consumed per animal-day. Several of these are computed from forage production and forage digestibility. For the typical examples given, the grazing use to maximize net profit on Arizona ponderosa pine ranges would be 30 to 38 percent. Apparently it is financially unwise to graze such ranges at greater than 40 percent because costs are likely to increase faster than gross returns.

Economics of Cattle Ranching

The economics of cattle ranching apparently follow similar patterns in many of the vegetation types. The size of the ranch operation and carrying capacity of the land both strongly affect the cost efficiency of producing beef (Boykin et al. 1966). Projected total costs for ranches producing more than 4,000 hundredweight of beef annually and having a 30 animal unit (AU) per section carrying capacity are only one-third as much per hundredweight as for ranches producing less than 200 to 300 hundredweight of beef annually and having a carrying capacity of 6 AU per section (Martin and Goss 1963).

If beef production is considered as the only ranch output, and real estate appreciation is ignored, returns to management are negative for all sizes and types of operations if capital is charged at its opportunity cost (Martin and Goss 1963). Computed net returns to capital and management vary from negative on small ranches to 1 or 2 percent on larger ranches, based on market prices of commercial ranches in Arizona. Regardless of the mix of public and private lands contained in the ranch operation, market prices are well above a rational value based on the capitalized value of the ranch's earning potential (Smith and Martin 1972). Because of economies of scale in cattle ranching, however, the marginal value product of an additional block of land may be considerably higher than the average value product of the whole ranch. Most ranches are much smaller than the size where long-run costs become constant (Martin 1966).

The capitalized value of an additional animal unit of grazing capacity to established ranches is currently $1,000 (O'Connell and Boster 1974). In other words, although it is not economically rational to purchase an entire ranch at prices approaching $1,000 per AU, it may be worthwhile to add to an existing ranch unit at these prices to improve economies of scale, or to spend equivalent sums to increase grazing capacity on existing lands.

Correlating Grazing with Other Uses

Water

The effects of grazing on water yield and quality are important, since the ponderosa pine type is the source of nearly half of the streamflow in the Salt River watershed in Arizona (Cooper 1959).

Brown et al. (1974) studied the effect of grazing on water yields. A watershed previously converted from ponderosa pine to a grass cover was grazed spring and fall, with the intent of removing 50 percent of the standing crop of perennial grasses during each grazing period. The 50 percent goal was not attained in several instances, but the total annual use on perennial grasses averaged nearly 60 percent for the period of the study. The grazing treatment has not increased water yield. This result can reasonably be applied to other ponderosa pine ranges in Arizona on heavy-textured volcanic soils.

Further tests are necessary to evaluate the impact of grazing on runoff from sedimentary soils, since grazing has affected runoff under some other conditions (Dunford 1949, Rauzi and Hanson 1966) and not under others (Rich and Reynolds 1963). The effects on erosion and sediment movement are likewise variable (Dunford 1949, Rich and Reynolds 1963) although, in general, erosion due to grazing has not been a major problem in the timbered areas of Arizona (USDA-FS 1936).

Timber

The primary negative impact of grazing on timber production is the potential damage to regeneration. Pearson (1927) suggested that grazing was the reason forest openings protected from fire failed to regenerate. There is considerable evidence that severe overstocking of livestock in the early days of forest grazing in the West did damage young timber reproduction. Apparently, sheep caused more damage than cattle. This damage was eventually recognized, and grazing guides were developed to reduce the damage.

It was suggested, but not proved, that thirst is an important factor causing sheep and cattle to browse pine seedlings, especially in the dry Arizona springtime (Cassidy 1936, 1937). If so, this damage can be alleviated by changing management and distribution of livestock water so that the trailing distance between water and green feed is reduced. It was also suggested that utilization rates be limited to 10 to 15 percent of the principal forage species during the spring drought so that plenty of forage is available (Crafts 1937).

Often, intensive silvicultural management can benefit production of both timber and forage. Thinning to increase the production of marketable timber

(Schubert 1971) will often increase forage production so long as thinning slash is not too dense.

Some authors feel that fire suppression policies have resulted in thickets of pine regeneration that have reduced the production of marketable timber and forage, and have changed the nature of the ponderosa pine forests (Weaver 1951, Humphrey 1959, Cooper 1960a). They conclude that both timber and forage production would benefit by allowing natural fires to burn. Pearson (1927), on the other hand, considered fire an enemy of maximum ponderosa pine timber yields.

Most reports on the effects of fire suppression policies and prescribed burning appear to be observational. The impact of low-intensity wildfires and prescribed burns on overall timber production has yet to be documented. While growth on crop trees may increase after fire, particularly in thinned areas, the net effect on many stands may be negative (Lindenmuth 1960, Pearson et al. 1972). The overall effects on forage plants are to (1) increase nutritional quality of plant growth, and (2) increase total herbage production as a result of thinning the timber stands.

Wildlife

Although the effect of livestock grazing on wildlife has not been specifically studied in the Arizona ponderosa pine type, an adequate forage supply is obviously important to big-game animals (Reynolds 1969, Clary and Larson 1971). Forage yields are highest in parks and forest openings, which are preferred by cattle and elk, and if the areas are not too large, by deer as well (Reynolds 1962c, 1969). This mutual preference by large herbivores creates the potential for competition. Results from the Beaver Creek watershed indicate that intensive livestock grazing can cause both deer (fig. 21) and elk to avoid an area (Neff 1972). The presence of some slash may tend to favor deer over cattle and therefore reduce direct competition (Reynolds 1966a, 1966b). Observations that light to moderate grazing by livestock seem to have little noticeable effect on big-game animals correspond with results from other areas (Julander 1962, Skovlin et al. 1968), although elk are probably more affected by cattle competition than are deer.

Reductions of the timber overstory, whether done primarily to improve yields of water, timber, or herbage, will virtually always increase herbage. Big-game usually respond to this improved forage supply if cover is not limiting (Neff 1972). While slash cleanup may be detrimental to deer use (Reynolds 1966a, Pearson 1968), other practices such as seeding exotic grasses may benefit elk. Seeding following wildfire improves the habitat for both elk and deer (Kruse 1972).

Little information appears to be available on most other wildlife species. Overgrazing is detrimental to turkey populations (fig. 22), but the degree of harm has not been documented (Lewis 1973). Some competition apparently occurs between livestock and pocket gophers (Turner et al. 1973), and considerable competition may occur between livestock and other rodents, such as prairie dogs (Taylor 1930). Studies on various grassland areas show that smaller wildlife species can be indirectly affected by grazing if the grazing influences the plant successional stage.

A great void remains in the knowledge of the impact of grazing and other management practices on the biota of an area, although the knowledge gap has been long recognized (Taylor 1927). The broad sponsorship of the recent Symposium on Management of Forest and Range Habitats for Nongame Birds (Smith 1975) indicates an intensifying interest in public management responsibility for wildlife species in addition to those traditionally supported by hunter interests.

Figure 21.—Deer are widespread throughout the Arizona ponderosa pine ranges.

Figure 22.—The Merriam's turkey is relatively common on many of the Arizona ponderosa pine ranges.

Emerging Resource Demands and Research Needs

Emerging Demands

Southwestern rangelands are becoming increasingly more important for values other than the production of domestic livestock. Open space, natural beauty, recreation, water, clean air, and wildlife are increasingly recognized as important rangeland values, particularly by the urban dweller.

In a similar vein, the public is becoming aware of and concerned about the management of public lands. Satisfaction of society's demands appears in large part to hinge on the maintenance of environmental quality. Fortunately, good range management is in harmony with environmental quality, and should deliver near-maximum returns to the livestock operator (Sampson 1952). In addition, **quality** range management does not appear to conflict with other forest uses and values, such as timber production, water quality and quantity, wildlife, and esthetics and recreation. A philosophical orientation toward environmental quality rather than maximum livestock production may seem financially disastrous at first, but the maintenance of a quality range does result in near-optimum long-term livestock production.

Although animal production can be increased through improved range condition and grazing management, it appears unlikely that ranch returns can be improved to the point that ranches are a rational economic investment at the marketplace under economic conditions similar to the 1960's through the mid-1970's. Without counting on continued real property appreciation, monies invested in livestock ranches for the past several years have far exceeded their ability to produce beef and income. Values other than revenue production have been strong motives in ranch ownership for some time (Smith and Martin 1972).

More information is needed for the ponderosa pine type concerning investment and returns for entire ranch operations and for specific management activities and improvements. In addition, information is needed on social and economic values of rangeland uses other than production of domestic livestock.

Some Additional Research Needs

A thorough knowledge of any ecosystem is necessary to appropriately apply management techniques. As part of that knowledge, rangelands need to be characterized and classified to provide a basis for the development and implementation of effective programs and policies. The Forest-Range Environmental Study (USDA-FS 1972a) has pointed out that efficient production of beef on western ranges in the future will require more intensive management on productive sites, and the elimination of grazing on unproductive or poor sites. These areas need to be identified. Extension of the habitat-typing work proposed by Region 3 of the USDA Forest Service[3] appears to be a good start on the problem.

Multiple use management, often complicated, is essential to maintaining both environmental quality and the economic base for rural communities. Manipulation of vegetation to increase livestock carrying capacity by such practices as timber harvesting, type conversion, selective plant control, and the introduction of new plant species can greatly influence such characteristics as habitat quality, landscape and recreational value, and water quality. The impacts of management practices on many forest uses and values are not well enough understood to provide a knowledge base suitable for consistently making the best management decision.

[3]*Chambers, John W. 1973. A prospectus for cooperative effort to classify habitat types in Region 3. (Unpublished report on file at office of Regional Forester, R-3, USDA-FS, Albuquerque, N.M.)*

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Common and Botanical Names of Plants Mentioned

Grasses and Grasslike Plants

Common Name	Botanical Name[4]
Bluegrass	*Poa* spp.
Bluegrass, big	*P. ampla*
Bluegrass, Kentucky	*P. pratensis*
Bluegrass, mutton	*P. fendleriana*
Bluestem, little	*Andropogon scoparius*
Brome, California	*Bromus carinatus*
Brome, mountain	*B. marginatus*
Brome, smooth	*B. inermis*
Deergrass	*Muhlenbergia rigens*
Dropseed, annual	*Sporobolus* spp.
Dropseed, black	*S. interruptus*
Dropseed, pine	*Blepharoneuron tricholepis*
Fescue, Arizona	*Festuca arizonica*
Grama, blue	*Bouteloua gracilis*
Junegrass, prairie	*Koeleria cristata*
Muhly, mountain	*Muhlenbergia montana*
Muhly, screwleaf	*M. virescens*
Muhly, spike	*M. wrightii*
Oatgrass, tall	*Arrhenatherum elatius*
Orchardgrass	*Dactylis glomerata*
Rye, mountain	*Secale montanum*
Rye, winter	*S. cereale*
Sedge	*Carex* spp.
Sedge, dryland	*C. geophila*
Squirreltail, bottlebrush	*Sitanion hystrix*
Threeawn, Arizona	*Aristida arizonica*
Threeawn, Fendler	*A. fendleriana*
Timothy	*Phleum pratense*
Wheatgrass, beardless	*Agropyron inerme*
Wheatgrass, bluebunch	*A. spicatum*
Wheatgrass, crested	*A. desertorum*
Wheatgrass, intermediate	*A. intermedium*
Wheatgrass, pubescent	*A. trichophorum*
Wheatgrass, slender	*A. trachycaulum*
Wheatgrass, tall	*A. elongatum*
Wheatgrass, western	*A. smithii*
Wildrye, blue	*Elymus glaucus*
Wildrye, Canada	*E. canadensis*
Wildrye, Russian	*E. junceus*

[4]Botanical names generally follow Kearney, Thomas H., Robert H. Peebles, and collaborators. 1969. Arizona flora. 1085 p. Univ. Calif. Press, Berkeley.

Forbs and Half-shrubs

Common Name	Botanical Name
Actinea, Cooper	*Hymenoxys cooperi*
Alfalfa, Grimm	*Medicago sativa* hort. var. Grimm
Alfalfa, Ladak	*M. sativa* hort. var. Ladak
Aster, showy	*Aster commutatus*
Bahia, ragleaf	*Bahia dissecta*
Beebalm	*Monarda* spp.
Bluets, Wrights	*Houstonia wrightii*
Bracken	*Pteridium* spp.
Bundleflower, James	*Desmanthus cooleyi*
Cinquefoil	*Potentilla* spp.
Cloakfern	*Notholaena sinuata*
Clover	*Trifolium* spp.
Cocklebur	*Xanthium* spp.
Conyza, Coulter	*Conyza coulteri*
Corydalis, golden	*Corydalis aurea*
Crazyweed, Lambert (or locoweed)	*Oxytropis lambertii*
Dandelion, common	*Taraxacum officinale*
Datura, sacred	*Datura meteloides*
Deathcamas	*Zigadenus paniculatus*
Deervetch	*Lotus* spp.
Dogbane, spreading (or Indian hemp)	*Apocynum* spp.
Ergot	*Claviceps* spp.
Eriogonum, redroot	*Eriogonum racemosum*
Eriogonum, sulfur	*E. cognatum*
False-hellebore	*Veratrum californicum*
Filaree	*Erodium cicutarium*
Fleabane	*E.* spp.
Fleabane	*Erigeron formosissimus*
Fleabane	*E. schiedeanus*
Fleabane, spreading	*E. divergens*
Fleabane, trailing	*E. flagellaris*
Geranium	*Geranium* spp.
Geranium, Fremont	*G. fremontii*
Gilia, woody	*Gilia multiflora*
Globemallow	*Sphaeralcea* spp.
Goats-beard (or salsify)	*Tragopogon dubius*
Golden-pea	*Thermopsis* spp.
Goldeneye, annual	*Viguiera annua*
Goldeneye, showy	*V. multiflora*
Goldenrod	*Solidago* spp.
Goldenrod, Missouri	*S. missouriensis*
Groundsel	*Senecio* spp.
Groundsel, threadleaf	*S. longilobus*
Horsetail	*Equisetum arvense*
Hymenoxys (or Actinea)	*Hymenoxys* spp.
Indigobush, white	*Dalea albiflora*
Iris (or flag)	*Iris* spp.
Knotweed, prostrate	*Polygonum aviculare*
Lambsquarters	*Chenopodium album*
Larkspur	*Delphinium* spp.
Lettuce, prickly	*Lactuca serriola*
Locoweed	Certain *Astragalus* spp. and *Oxytropsis lambertii*
Lupine	*Lupinus* spp.
Meadowrue	*Thalictrum fendleri*
Milkvetch	*Astragalus* spp.

Forbs and Half-shrubs (cont.)

Common Name	Botanical Name
Milkvetch	*A. tephrodes*
Milkvetch, slender	*A. recurvus*
Milkweed, whorled	*Asclepias subverticillata*
Mock-pennyroyal	*Hedeoma* spp.
Monkshood, western	*Aconitum columbianum*
Mullein	*Verbascum* spp.
Mullein, flannel	*V. thapsis*
Mustard, annual	*Brassica* spp.
Nightshade, cutleaf	*Solanum triflorum*
Paintbrush	*Castilleja* spp.
Paperflower	*Psilostrophe* spp.
Pea, red-and-yellow	*Lotus wrightii*
Peavine	*Lathyrus* spp.
Penstemon (or beard tongue)	*Penstemon* spp.
Phlox	*Phlox woodhousei*
Pussytoes	*Antennaria* spp.
Pussytoes, Rocky Mountain	*A. aprica*
Ragweed, western	*Ambrosia psilostachya*
Rubberweed, Colorado (or pingue)	*Hymenoxys richardsonii*
Russianthistle	*Salsola kali*
Sagebrush, flat	*Artemisia carruthii*
Sandwort	*Arenaria* spp.
Snakeweed, broom	*Gutierrezia sarothrae*
Sneezeweed, western	*Helenium hoopesii*
Spurge (or euphorbia)	*Euphorbia* spp.
Sweetclover	*Melilotus* spp.
Sweetclover, white	*M. albus*
Sweetclover, yellow	*M. officinalis*
Tansy-mustard	*Descurainia pinnata*
Thistle	*Cirsium* spp.
Thistle, Wheeler	*C. wheeleri*
Toadflax	*Comandra* spp.
Vetch, American	*Vicia americana*
Vetch, sweetclover	*V. pulchella*
Violet	*Viola* spp.
Water-hemlock, Douglas	*Cicuta douglasii*
White-ragweed	*Hymenopappus lugens*
Willowweed, autumn	*Epilobium paniculatum*
Wormwood, Louisiana	*Artemisia ludoviciana*
Yarrow	*Achillea* spp.
Yarrow, western	*A. lanulosa*

Trees and Shrubs

Common Name	Botanical Name
Apache-plume	*Fallugia paradoxa*
Aspen, quaking	*Populus tremuloides*
Boxleaf, myrtle	*Pachystima mysinites*
Ceanothus, Fendler (or buckbrush)	*Ceanothus fendleri*
Cliffrose	*Cowania mexicana*
Chokecherry	*Prunus virginiana*
Currant, wax	*Ribes cereum*
Douglas-fir	*Pseudotsuga menziesii*
Elder, blueberry	*Sambucus coerulea*
Fendlerella	*Fendlerella utahensis*
Fernbush	*Chamaebatiaria millefolium*
Jamesia, cliff	*Jamesia americana*
Juniper	*Juniperus* spp.
Juniper, alligator	*J. deppeana*
Juniper, common	*J. communis*
Horsebrush, gray	*Tetradymia canescens*
Locust, New-Mexican	*Robinia neomexicana*
Mahonia, creeping (or Oregon grape)	*Berberis repens*
Manzanita, greenleaf	*Arctostaphylos patula*
Mockorange, littleleaf	*Philadelphus microphyllus*
Mountainmahogany	*Cercocarpus* spp.
Ninebark, mountain	*Physocarpus monogynus*
Oak, Gambel	*Quercus gambelii*
Pine, ponderosa	*Pinus ponderosa*
Pinyon	*Pinus edulis*
Rabbitbrush, Parry	*Chrysothamnus parryi*
Raspberry, American red	*Rubus strigosus*
Rockspiraea, bush	*Holodiscus dumosus*
Rose	*Rosa* spp.
Sagebrush, big	*Artemisia tridentata*
Sagebrush, black	*A. nova*
Snowberry	*Symphoricarpos* spp.
Sumac, skunkbush	*Rhus trilobata*

Clary, Warren P.
1975. Range management and its ecological basis in the ponderosa pine type of Arizona: The status of our knowledge. USDA For. Serv. Res. Pap. RM-158, 35 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521

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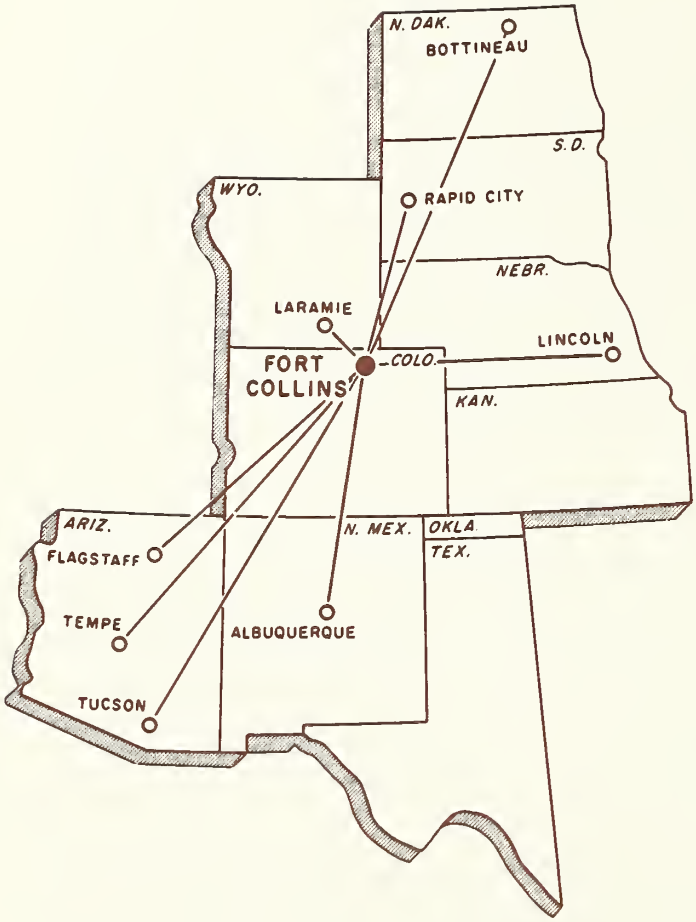
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